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Text

FINAL SUPPLEMENT ENVIRONMENTAL IMPACT STATEMENT

Waste Isolation Pilot Plant

Volume 1 of 13

January 1990

U.S. DEPARTMENT OF ENERGY
Office of Environmental Restoration
and Waste Management

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U.S. DEPARTMENT OF ENERGY
Office of Environmental Restoration
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Washington, D.C. 20585

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COVER SHEET

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Lead Agency: U.S. Department of Energy (DOE)
Cooperating Agency: U.S. Department of the Interior, Bureau of Land Management (BLM)

TITLE:

Final Supplement, Environmental Impact Statement, (SEIS), Waste Isolation Pilot Plant (WIPP)

CONTACT:

For further information, contact:

1) Project Manager
WIPP Supplemental Environmental Impact Statement Office
P. O. Box 3090
Carlsbad, New Mexico 88220
(800) 274-0585

2) Carol Borgstrom, Director
Office of NEPA Project Assistance
Office of the Assistant Secretary for Environment, Safety and Health
U.S. Department of Energy (EH-25)
1000 Independence Avenue, SW
Washington, D.C. 20585
(202) 586-4600

3) William Dennison
Acting Assistant General Counsel for Environment
U.S. Department of Energy (GC-11)
1000 Independence Avenue, SW
Washington, D.C. 20585
(202) 586-6947

ABSTRACT:

In 1980, the DOE published the Final Environmental Impact Statement (FEIS) for the WIPP. This FEIS analyzed and compared the environmental impacts of various alternatives for demonstrating the safe disposal of transuranic (TRU) radioactive waste resulting from DOE national defense related activities. Based on the environmental analyses in the FEIS, the DOE published a Record of Decision in 1981 to proceed with the phased development of the WIPP in southeastern New Mexico as authorized by the Congress in Public Law 96-164.

Since publication of the FEIS, new geological and hydrological information has led to changes in the understanding of the hydrogeological characteristics of the WIPP site as they relate to the long-term performance of the underground waste repository. In addition, there have been changes in the information and assumptions used to analyze the environmental impacts in the FEIS. These changes include: 1) changes in the composition of the TRU waste inventory, 2) consideration of the hazardous chemical constituents in TRU waste, 3) modification and refinement of the system for the transportation of TRU waste to the WIPP, and 4) modification of the Test Phase.

The purpose of this SEIS is to update the environmental record established in 1980 by evaluating the environmental impacts associated with new information, new circumstances, and proposal modifications. This SEIS evaluates and compares the Proposed Action and two alternatives.

The Proposed Action is to proceed with a phased approach to the development of the WIPP. Full operation of the WIPP would be preceded by a Test Phase of approximately 5 years during which time certain tests and operational demonstrations would be carried out. The elements of the Test Phase, tests and operations demonstration, continue to evolve. These elements are currently under evaluation by the DOE based on comments from independent groups such as the Blue Ribbon Panel, the National Academy of Sciences, the Environmental Evaluation Group, and the Advisory Committee on Nuclear Facility Safety. At this time, the Performance Assessment tests would be comprised of laboratory-scale, bin-scale, and alcove-scale tests. The DOE, in December 1989, issued a revised draft final Test Phase plan that focuses on the Performance Assessment tests to remove uncertainties regarding compliance with long-term disposal standards (40 CFR 191 Subpart B) and to provide confirming data that there would be no migration of hazardous constituents (details are available in Subsection 3.1.1.4 and Appendix O). The tests would be conducted to reduce uncertainties associated with the prediction of natural processes that might affect long-term performance of the underground waste repository. Results of these tests would be used to assess the ability of the WIPP to meet applicable Federal standards for the long-term protection of the public and the environment. The operational demonstrations would be conducted to show the ability of the TRU waste management system to certify, package, transport, and emplace TRU waste in the WIPP safely and efficiently. Waste requirements for the Integration Operations Demonstration remain uncertain. A separate document would be developed to describe in detail the Integration Operations Demonstration following the DOE's decision as to the scope and timing of the demonstration.

During the Test Phase, National Environmental Policy Act (NEPA) requirements would be reviewed in light of the new information developed and appropriate documentation would be prepared. In addition, the DOE will issue another SEIS at the conclusion of the Test Phase and prior to a decision to proceed to the Disposal Phase. This SEIS will analyze in more detail the system-wide impacts of processing and handling at each of the generator/storage facilities and will consider the system-wide impacts of potential waste treatments.

Upon completion of the Test Phase, the DOE would determine whether the WIPP would comply with U.S. Environmental Protection Agency (EPA) standards for the long-term disposal of TRU waste (i.e., 40 CFR Part 191, Subpart B; 40 CFR Part 268). The WIPP would enter the Disposal Phase if there was a favorable Record of Decision based on the new SEIS to be prepared prior to the Disposal Phase and if there was a determination of compliance with the EPA standards and other regulatory requirements. During this phase, defense TRU waste generated since 1970 would be shipped to and disposed of at the WIPP. After completion of waste emplacement, the surface facilities would be decommissioned, and the WIPP underground facilities would serve as a permanent TRU waste repository.

The first alternative, No Action, is similar to the No Action Alternative discussed in the 1980 FEIS. Under this alternative, there would be no research and development facility to demonstrate the safe disposal of TRU waste, and TRU waste would continue to be stored. Storage of newly generated TRU mixed waste would be in conflict with the Resource Conservation and Recovery Act (RCRA) Land Disposal Restrictions; treatment would be required to avoid such conflict. The WIPP would be decommissioned as a waste disposal facility and potentially put to other uses.

The second alternative to the Proposed Action is to conduct the bin-scale tests at a facility other than the WIPP and to delay emplacement of TRU waste in the WIPP underground until a determination has been made of compliance with the EPA standards for TRU waste disposal (i.e., 40 CFR Part 191, Subpart B). The bin-scale tests could be conducted outside the WIPP underground facilities in a specially designed, aboveground facility. The implications of this alternative include delays in both the operational demonstrations and alcove-scale tests, the lack of alcove-scale test data for the compliance demonstration, and placing the WIPP facilities in a "standby" mode. The specialized facility for aboveground bin-scale tests could be constructed at any one of the DOE facilities. In order to analyze the environmental impacts of this alternative in the final SEIS, the DOE has evaluated the Idaho National Engineering Laboratory in Idaho as a representative facility for the aboveground bin-scale tests.

ADDITIONAL INFORMATION:

The 1980 FEIS was reprinted and provided to the public with the draft SEIS which was published April 21, 1989. Public comments on the draft SEIS were accepted for a period of 90 days after publication. During that time, public hearings were conducted in Atlanta, Georgia; Pocatello, Idaho; Denver, Colorado; Pendleton, Oregon; Albuquerque, Santa Fe and Artesia, New Mexico; Odessa, Texas; and Ogden, Utah.

This final SEIS for the WIPP project is a revision of the draft SEIS published in April 1989. It includes responses to the public comments received in writing and at the public hearings and revisions of the draft SEIS in response to the public comments. Revisions of importance have been identified in this final SEIS by vertical lines in the margins to highlight changes made in response to comments.

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Volumes 1 through 3 of the final SEIS contain the text, appendices, and the summary comments and responses, respectively. Volumes 6 through 13 of the final SEIS contain reproductions of all of the comments received on the draft SEIS, and Volumes 4 and 5 contain the indices to Volumes 6 through 13. An Executive Summary and/or Volumes 1 through 5 of the final SEIS have been distributed to those who received the draft SEIS or requested a copy of the final SEIS. Although not distributed to all who commented on the draft SEIS, Volumes 1 through 13 of the final SEIS have been placed in the reading rooms and libraries listed in Appendix K; these volumes will be mailed to the general public upon request.

A notice of availability of the final SEIS has been published by the EPA in the Federal Register. The DOE will make a decision on implementation of the Proposed Action or the alternatives no earlier than 30 days after publication of the EPA notice of availability. The DOE's decision will be documented in a publicly available Record of Decision to be published in the Federal Register and distributed to all who receive this final SEIS.

Foreword

In October 1989, the Secretary of Energy issued a draft Decision Plan for the Waste Isolation Pilot Plant (WIPP). The Decision Plan listed all key technical milestones and institutional activities for which Departmental, Congressional, or State actions are required prior to receipt of waste for the proposed Test Phase, which is the next step in the phased development of the WIPP. The Plan was issued for review to States, Congressional representatives, other Federal agencies (including the Environmental Protection Agency and the Department of the Interior), and oversight groups (e.g., the Advisory Council for Nuclear Facility Safety, the Blue Ribbon Panel, the National Academy of Sciences, and the Environmental Evaluation Group). Revision 1 of the Plan was issued in December 1989.

Departmental activities required prior to receipt of waste at the WIPP include completion of the "as-built" drawings for the facility, the Energy Systems Acquisition Advisory Board review process, waste-hoist repairs, preoperational appraisal and operational readiness review, mining and outfitting of the alcoves for the proposed Test Phase, and completion of this Supplement to the Environmental Impact Statement.

Other Departmental activities include completion of the Final Safety Analysis Report (FSAR) and issuance of the FSAR addenda to address the proposed Test Phase and associated waste retrieval (if necessary). Future Departmental activities include the planned issuance of the EPA Standards Compliance Summary Report and the evaluation of waste form treatments and design modifications that may be required to meet the EPA Subpart B disposal standards.

Key activities involving oversight groups include final development of an acceptable retrievability program to demonstrate that waste emplaced during the first five years of the facility operation are fully retrievable, and an integrated waste handling demonstration using simulated wastes to ensure system-wide readiness for receipt of wastes for the Test Phase.

Institutional activities include concurrent pursuance of legislative and administrative land withdrawal (legislative withdrawal is the process preferred by the Department); the EPA's ruling on the DOE's No-Migration Variance Petition in compliance with the Land Disposal Restrictions under the Resource Conservation and Recovery Act (RCRA); resolution of regulatory issues, including the State of New Mexico's authority to regulate mixed waste under the RCRA and the designation of routes to be used for transport of transuranic waste; Departmental resolution of any mineral lease at the WIPP; and completion of appropriate agreements with the Western Governors Association and Southern States Energy Board.

This Supplemental Environmental Impact Statement (SEIS) is one of a number of milestones which are critical to the opening of the Waste Isolation Pilot Plant. This SEIS provides an upper bound of the potential impacts of the Proposed Action and alternatives. Based on this final SEIS, the Department will issue a Record of Decision no sooner than 30 days after the EPA publishes a notice of availability in the Federal Register.

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TABLE OF CONTENTS

COVER SHEET iii

FOREWORD vii

TABLE OF CONTENTS ix

LIST OF FIGURES xv

LIST OF TABLES xix

Section — Page

1.0 PURPOSE AND NEED FOR ACTION 1-1

1.1 BACKGROUND 1-1

1.2 NEPA COMPLIANCE 1-2
1.2.1 1980 WIPP FEIS 1-2
1.2.2 NEPA Documentation Since the FEIS 1-4

1.3 PURPOSE AND NEED FOR SUPPLEMENT TO FEIS 1-4

1.4 PROPOSED ACTION 1-5

1.5 CONTENT OF THE SEIS 1-7

1.6 OVERVIEW OF PUBLIC PARTICIPATION AND INTERGOVERNMENTAL AFFAIRS 1-8

REFERENCES FOR SECTION 1 1-21

2.0 BACKGROUND: AN OVERVIEW OF THE WIPP 2-1

2.1 LOCATION 2-1

2.2 FACILITIES 2-5

Section Page

2.2.1 Surface Facilities 2-5
2.2.2 Underground Facilities 2-8

2.3 WASTE TYPES AND FORMS 2-8
2.3.1 Waste Acceptance Criteria (WAC) 2-10
2.3.2 Processing of TRU Waste 2-12

2.4 WASTE RECEIPT AND EMPLACEMENT 2-13
2.4.1 Waste Receipt 2-14
2.4.2 Waste Emplacement 2-14

2.5 WASTE RETRIEVAL AT THE WIPP 2-15

2.6 PLANS FOR DECOMMISSIONING 2-17

2.7 SITE EMERGENCY PLANNING AND SECURITY 2-18

2.8 TRANSPORTATION EMERGENCY PLANNING 2-20

2.9 ENVIRONMENTAL MONITORING PROGRAMS 2-22
2.9.1 Radiological Baseline Program (RBP) 2-22
2.9.2 Ecological Monitoring Program (EMP) 2-23
2.9.3 Cooperative Raptor Research and Management Program 2-24
2.9.4 Operational Environmental Monitoring Program (OEMP) 2-24
2.9.5 Environmental Evaluation Group Monitoring Program 2-25

REFERENCES FOR SECTION 2 2-26

3.0 DESCRIPTION OF THE PROPOSED ACTION AND ALTERNATIVES 3-1

3.1 PROPOSED ACTION 3-1
3.1.1 Changes to the Proposed Action and New Information or Circumstances 3-2

3.2 ALTERNATIVES 3-34
3.2.1 No Action Alternative 3-34
3.2.2 Alternative Action 3-43

3.3 ALTERNATIVES NOT CONSIDERED IN DETAIL 3-44

REFERENCES FOR SECTION 3 3-46

Section Page

4.0 DESCRIPTION OF THE EXISTING ENVIRONMENT AT THE WIPP SITE . 4-1

4.1 EXISTING ENVIRONMENT 4-1
4.1.1 Biological Environment 4-1
4.1.2 Socioeconomic Environment 4-2
4.1.3 Transportation 4-3
4.1.4 Land Use 4-3
4.1.5 Air Quality 4-3
4.1.6 Cultural Resources 4-4
4.1.7 Background Radiation 4-4

4.2 GEOLOGY 4-5
4.2.1 Regional Geology 4-5
4.2.2 Stratigraphic Setting of the WIPP Site 4-7

4.3 HYDROLOGY AND WATER QUALITY 4-13
4.3.1 General Setting 4-13
4.3.2 Salado Formation 4-14
4.3.3 Rustler Formation 4-39
4.3.4 Castile Formation 4-68
4.3.5 Bell Canyon Formation 4-73

REFERENCES FOR SECTION 4 4-74

5.0 ENVIRONMENTAL CONSEQUENCES 5-1

5.1 ENVIRONMENTAL IMPACTS OF IMPLEMENTATION OF FEIS SELECTED ALTERNATIVE 5-1
5.1.1 Biology 5-1
5.1.2 Socioeconomics 5-3
5.1.3 Land Use 5-6
5.1.4 Air Quality 5-6
5.1.5 Cultural Resources 5-7

5.2 ENVIRONMENTAL IMPACTS OF SEIS PROPOSED ACTION 5-7
5.2.1 Waste Retrieval, Handling, and Processing at DOE Facilities 5-7
5.2.2 Transportation 5-24
5.2.3 Risk Assessment and Analysis of Radiological Environmental Consequences of Operations and Possible Retrieval of Waste at the WIPP 5-57

Section

Page

5.2.4 Risk Assessment and Analysis of Hazardous Chemical Environmental Consequences of Operations and Possible Retrieval of Waste at the WIPP 5-81

5.3 SEIS ALTERNATIVE ACTION 5-112
5.3.1 Biology 5-113
5.3.2 Socioeconomics 5-113
5.3.3 Land Use 5-114
5.3.4 Air Quality 5-114
5.3.5 Cultural Resources 5-115
5.3.6 Water Quality 5-115
5.3.7 Transportation 5-115
5.3.8 Radiological Assessment: Operations 5-116
5.3.9 Chemical Assessment: Operations 5-124

5.4 DECOMMISSIONING AND LONG-TERM PERFORMANCE 5-127
5.4.1 Environmental Consequences of Decommissioning 5-127
5.4.2 Postoperational Performance 5-127
5.4.2.1 Changes from the FEIS 5-127
5.4.2.2 Description of Approach and Data Selection 5-130
5.4.2.3 Narrative Descriptions of the Release Scenarios . 5-133
5.4.2.4 Analysis of Scenarios: Initial Conditions 5-140
5.4.2.5 Analysis of Scenarios: Cases IA, IB, and IC 5-152
5.4.2.6 Analysis of Scenarios: Cases IIA, IIA (rev), IIB, IIC, IIC (rev), and IID 5-162
5.4.2.7 Another Scenario Not Evaluated in Detail 5-192
5.4.2.8 Summary and Observations 5-193

5.5 NO ACTION ALTERNATIVE 5-200
5.5.1 Generator/Storage Facilities 5-201
5.5.2 WIPP Site 5-208

REFERENCES FOR SECTION 5 5-210

6.0 MITIGATION MEASURES 6-1

6.1 INTRODUCTION 6-1

6.2 CONSTRUCTION-, TEST AND DISPOSAL PHASES-, AND TRANSPORTATION-RELATED MITIGATION MEASURES 6-2

6.3 LONG-TERM FACILITY PERFORMANCE ENGINEERING MODIFICATIONS 6-7
6.3.1 Engineering Modifications Related to Geologic Parameters 6-7

Section | Page

6.3.2 Engineering Modifications Related to Hydrology and Water Quality 6-9

6.4 MITIGATION BY WASTE TREATMENT 6-16
6.4.1 Waste Treatment Technologies 6-16
6.4.2 Effects of Waste Treatment 6-21

REFERENCES FOR SECTION 6 6-25

7.0 UNAVOIDABLE ADVERSE IMPACTS 7-1

7.1 CONSTRUCTION 7-1
7.1.1 Upgrade of Site Security Facilities 7-1
7.1.2 Cost Reduction Program 7-2

7.2 OPERATION 7-3

7.3 IMPACTS AFTER DECOMMISSIONING 7-4

7.4 COMPARISON OF ALTERNATIVES 7-4

REFERENCES FOR SECTION 7 7-5

8.0 SHORT-TERM USES AND LONG-TERM PRODUCTIVITY 8-1

REFERENCES FOR SECTION 8 8-2

9.0 IRREVERSIBLE AND IRRETRIEVABLE COMMITMENTS OF RESOURCES 9-1

9.1 CONSTRUCTION 9-1

9.2 OPERATION. 9-1

REFERENCES FOR SECTION 9 9-3

10.0 ENVIRONMENTAL REGULATORY REQUIREMENTS AND OVERSIGHT ORGANIZATIONS 10-1

10.1 REGULATORY COMPLIANCE COMMITMENT AND STRATEGY . . . 10-1

Section | Page

10.2 PERMITS AND APPROVALS 10-4
10.2.1 Resource Conservation and Recovery Act of 1976 10-4
10.2.2 Clean Air Act 10-10
10.2.3 Federal Land Policy and Management Act 10-10
10.2.4 Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level, and Transuranic Radioactive Waste (40 CFR Part 191) 10-12
10.2.5 Nuclear Regulatory Commission (NRC) TRUPACT-II Certification 10-14
10.2.6 Transportation Regulations 10-15
10.2.7 Final Safety Analysis Report 10-17

10.3 OVERSIGHT ORGANIZATIONS 10-17
10.3.1 Environmental Protection Agency 10-18
10.3.2 State of New Mexico 10-18
10.3.3 National Academy of Sciences 10-21
10.3.4 Advisory Committee on Nuclear Facility Safety 10-22
10.3.5 "Blue Ribbon Review Panel" 10-22
10.3.6 Mine Safety and Health Administration (MSHA) 10-22

REFERENCES FOR SECTION 10 10-23

GLOSSARY GLO-1

ABBREVIATIONS AND ACRONYMS AC-1

LIST OF PREPARERS LP-1

APPENDICES . . . . . VOLUME II

LIST OF FIGURES

Figure		Page
1.1	Key WIPP activities	1-3
2.1	Location of the WIPP site	2-2
2.2	Control zones at the WIPP site	2-3
2.2a	WIPP site land withdrawal boundary	2-4
2.3	Surface facilities at the WIPP	2-6
2.4	Schematic of the WIPP repository	2-9
3.1	Cross section of TRUPACT-II	3-13
3.1a	Standard Waste Box	3-16
3.2	Cross section of NUPAC 72B cask	3-18
3.3	Typical tractor-trailer combination for TRU waste transport	3-22
3.4	Schematic of the TRANSCOM	3-23
3.5	Proposed TRU waste truck transportation routes	3-24
3.6	Proposed mainline railroad routes for TRU waste transportation to the WIPP	3-26
4.1	Major geologic events affecting southeastern New Mexico and western Texas	4-6
4.2	Geologic column and cross section of the New Mexico-Texas region	4-8
4.3	Major regional structures	4-9
4.4	Generalized stratigraphic column for the WIPP site	4-10

Figure Page

4.5 Generalized stratigraphic cross section of the Salado and Castile Formations between boreholes Cabin Baby-1 and WIPP-11 4-11

4.6 Borehole locations for generalized stratigraphic cross section of the Salado and Castile Formations 4-12

4.7 Hydrologic boreholes and wells at and near the WIPP site 4-15

4.8 Summary of formation conductivities 4-28

4.9 Summary of fluid formation pressures 4-29

4.9a Approximate layout of the WIPP, showing both experimental (northern) and waste-emplacement (southern) portions of the underground workings 4-32

4.9b Relationship of MB139 to repository level stratigraphic sequence 4-33

4.10 Compositional variability of Salado Formation fluids 4-40

4.11 Hydrostratigraphic column of the Rustler Formation in the vicinity of the WIPP site 4-42

4.12 Pumping and observation wells for the WIPP-13 multipad interference test 4-47

4.13 Pumping and observation wells for the H-3 multipad interference test ... 4-48

4.14 Estimated freshwater heads of the Culebra Dolomite member 4-49

4.15 Water levels and estimated freshwater heads in the Magenta Dolomite member 4-51

4.16 Boreholes at and near the WIPP site 4-56

4.17 1987 Calculated transmissivities and flow directions for the Culebra Dolomite member 4-60

4.18 1988 Calculated transmissivities for the Culebra Dolomite member at and near the WIPP site 4-63

4.18a1989 transient calibrated transmissivity field of the Culebra Dolomite 4-64

4.19 Summary of hydrochemical facies and local flow directions in the Culebra Dolomite member 4-67

Figure | Page

4.20 Generalized distribution of Castile Formation brine occurrences and approximate extent of the Castile "disturbed zone" in the northern Delaware Basin 4-69

4.21 Contour map of apparent depth to first major deep conductor 4-72

5.1 Schematic of Shaft Seal System in the Salado Formation 5-134

5.2 Representative plan for plugging a borehole through the repository to a Castile Formation brine reservoir 5-138

5.3 Void reduction during room closure 5-143

5.3a Pressure history to initial closure of storage area, showing the effects of gas and waste backpressure 5-144

5.4 Schematic of the repository for Case I, undisturbed performance 5-156

5.5 Numerical flow network input for simulation of Cases IA, IB, and IC . . . 5-158

5.6 Schematic of the repository and underlying Castile Formation brine reservoir for Case II, performance when disturbed by human intrusion 5-169

5.7 Diagram of groundwater flow near the point where water from the intruding borehole enters Culebra aquifer flow 5-172

5.8 Flow rates to the Culebra Dolomite from the breach borehole for Case IIA (rev) and IIC (rev) 5-175

5.9 Concentration profiles along the plume centerline for stable Pb at 10,000 years, Case IIA (rev) 5-179

5.10 Concentration profiles along the plume centerline for ^{238}Pu decay chain at 10,000 years, Case IIA (rev) 5-181

5.11 Concentration profiles along the plume centerline for stable Pb at 10,000 years, Case IIC (rev) 5-182

5.12 Breakthrough concentrations at stock well for stable Pb as a function of time, Case IIC (rev) 5-183

5.13 Lateral concentration profile at stock well for stable Pb at 10,000 years, Case IIC (rev) 5-184

Figure Page

5.14 Concentration profiles along the plume centerline for ^{238}Pu decay chain at 10,000 years, Case IIC (rev) 5-185

5.15 Breakthrough concentrations at stock well for ^{238}Pu decay chain as a function of time, Case IIC (rev) 5-186

5.16 Radiation doses to individuals who eat beef from cattle watered at the stock well, Case IIC (rev) 5-191

6.1 Tentative locations of panel seals 6-12

6.2 Schematic of tunnel seal 6-13

6.3 Schematic of shaft seal system in the Salado Formation 6-14

6.4 Schematic of shaft seal system in the Rustler Formation 6-15

LIST OF TABLES

Table		Page
1.1	Cross-references between the FEIS and the SEIS by section number	1-10
3.1	Estimated volumes of CH TRU waste in retrievable storage or projected to be generated through the year 2013	3-3
3.2	Estimated volumes of RH TRU waste in retrievable storage or projected to be generated through the year 2013	3-5
3.3	Summary of average TRU waste characteristics	3-8
3.4	Estimated maximum concentrations of hazardous chemical constituents in TRU mixed waste from the Rocky Flats Plant	3-11
3.5	Minimum regulatory testing requirements vs. actual TRUPACT-II certification testing program	3-15
3.6	Highway mileage for DOT-approved truck transportation routes	3-25
3.7	Railroad mileage for rail transportation routes	3-27
4.1	Hydrologic issues: FEIS vs. Current (modified from Lappin et al., 1989)	4-16
4.2	Summary of 1984 Phase 2 underground facility gas flow test results (modified from Stormont et al., 1987)	4-22
4.3	Summary of N1420 initial tests (modified from Stormont et al., 1987)	4-23
4.4	Summary of N1420 follow-up (modified from Stormont et al., 1987)	4-24
4.5	Summary of first panel tests	4-25
4.6	Summary of the results of 1987 hydrologic testing in the WIPP waste handling shaft	4-27
4.7	DRZ assumptions used in Lappin et al., (1990) for closure modeling versus known characteristics	4-35
4.8	Geochemistry of PAB 2	4-41

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Table | Page

4.9 Transmissivity data bases used in the numerical modeling of the Culebra Dolomite by Barr et al., (1983), Haug et al., (1987), and LaVenue et al., (1988) 4-53

4.10 Detailed summary of the results of recent single-well tests in the Culebra Dolomite (Beauheim, 1987b) 4-54

4.11 Summary of the results of single-pad interference tests in the Culebra Dolomite at the H-3 and H-11 hydropads 4-57

4.12 Summary of the analytical interpretation of results from the H-3 multipad interference test 4-59

4.13 Summary of the analytical interpretation of results from the WIPP-13 multipad interference test 4-62

5.1 The WIPP's influence on the regional economies of Eddy and Lea Counties, FY 1988 5-5

5.2 Summary of radiological consequences to the public from accidental or abnormal releases during RWMC/SWEPP operations with stored TRU waste 5-11

5.3 Summary of radiological consequences to the maximally exposed worker from accidental or abnormal events during RWMC/SWEPP operations with stored TRU waste 5-12

5.4 Excess cancer risks due to accidents associated with RWMC/SWEPP operations with TRU stored waste 5-13

5.5 Summary of consequences from postulated accidents during retrieval at the Savannah River Site 5-17

5.6 Summary of consequences from postulated accidents during retrieval in the TRU Waste Processing Facility at the Savannah River Site 5-18

5.7 Population total-body dose commitments (person-rem) from the processing of retrievably stored and newly generated CH TRU waste at the Hanford Reservation Waste Retrieval and Processing Facility 5-19

Table | Page

5.8 Maximum individual total-body dose commitments (rem) from the processing of retrievably stored and newly generated CH TRU waste at the Hanford Reservation Waste Retrieval and Processing Facility 5-19

5.9 Projected TRU waste shipments and radiological exposure from waste shipments to the WIPP 5-27

5.10 Annual radiological exposures (person-rem) for CH TRU Proposed Action waste shipments to the WIPP 5-29

5.11 Annual radiological exposures (person-rem) for RH TRU Proposed Action waste shipments to the WIPP 5-31

5.12 Estimated maximum exposure to individuals within various population categories from incident-free transportation during the Test Phase and Disposal Phase for the Proposed Action and during the Disposal Phase for the Alternative Action (rem) 5-33

5.13 Estimated annual average exposure (rem) for the hypothetical maximally exposed member of the general public (nonoccupational exposure) 5-37

5.14 Human health risks associated with radiological exposures during Proposed Action transportation to the WIPP 5-42

5.15 Quantities of volatile organic compounds available for release during accident scenarios 5-48

5.16 Estimated exposures to volatile organic compounds and associated risks from a transportation accident involving truck shipments 5-49

5.17 Estimated exposures to volatile organic compounds and associated risks from a transportation accident involving rail shipments 5-50

5.18 Exposures and risk associated with releases of lead during an upper-bound accident scenario 5-52

5.19 Air pollutant unit consequence factors 5-54

5.20 Nonradiological and nonchemical unit risk factors 5-55

5.21 Per shipment nonradiological risk of waste shipments 5-56

5.22 Routine radionuclide releases to the WIPP environment during the Proposed Action (total activity in curies/year) 5-67

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Table | Page

5.23 Annual radiation exposure to the public from routine operations during the Proposed Action 5-68

5.24 Annual occupational radiation exposure from routine operations during the Proposed Action (person-rem/year) 5-69

5.25 Estimated occupational and off-site radiation exposures for routine CH waste retrieval activities 5-71

5.26 Accident scenarios involving CH waste 5-72

5.27 Accident scenarios involving RH waste 5-73

5.28 Radiation releases and exposures from credible accident scenarios during WIPP facility operation 5-75

5.29 Risks associated with routine radiological releases from WIPP operations during the Proposed Action 5-77

5.30 Maximum worker, general population, and maximum individual risks associated with worst-credible, accidental radiological releases from the WIPP during the Proposed Action 5-78

5.31 Estimated concentrations of hazardous constituents in TRU mixed waste from the Rocky Flats Plant 5-87

5.32 Hazardous chemical constituents reported in CH TRU mixed waste for which no estimates on concentrations are available 5-88

5.33 Average concentrations of selected volatile organic compounds in the headspace of TRU waste drums 5-91

5.34 Number of drums containing detectable quantities of selected organics in TRU waste from the Rocky Flats Plant 5-91

5.35 Average emission rates of selected volatile organic compounds through the carbon composite filters of TRU waste drums 5-93

5.36 Estimated emission periods for volatile organics based on total concentrations and emission rates through the container filter 5-94

5.37 Occupational exposures and estimated daily intakes during aboveground operations 5-96

5.38 Occupational exposures from underground operations 5-98

Table | Page

5.39 Routine maximum estimated daily intakes for underground operations . . . 5-99

5.40 Residential exposures and estimated daily intakes during aboveground operations . . . 5-101

5.41 Residential exposures and estimated daily intakes during underground operations . . . 5-102

5.42 Releases, worker exposures, and estimated intakes from projected accidents during WIPP facility operations . . . 5-104

5.43 Maximum incremental lifetime cancer risks for routine releases . . . 5-107

5.44 Maximum hazard indices for routine releases . . . 5-108

5.45 IDLH-based hazard indices (HIs) for accidents during routine operations . . . 5-110

5.46 TLV-based hazard indices (HIs) . . . 5-111

5.47 Annual radiological exposures (person-rem) for CH TRU Alternative Action waste shipments to the WIPP . . . 5-117

5.48 Annual radiological exposures (person-rem) for RH TRU Alternative Action waste shipments to the WIPP . . . 5-119

5.49 Estimated annual average exposure for the hypothetical maximally exposed member of the general public (nonoccupational exposure) . . . 5-120

5.50 Human health risks associated with radiological exposures during Alternative Action transportation to the WIPP . . . 5-121

5.51 Routine radionuclide releases to the WIPP environment during the Alternative Action (total activity in curies/year) . . . 5-122

5.52 Annual radiation exposure to the public from routine operations during the Alternative Action . . . 5-123

5.53 Annual occupational radiation exposure from routine operations during the Alternative Action (person-rem/year) . . . 5-123

5.54 Population risks associated with routine radiological releases from WIPP operations during the Alternative Action . . . 5-125

UNIV. OF ILLINOIS URBANA-CHAMPAIGN

Table | Page

5.55 Maximum individual and general population risks associated with worst-credible accidental radiological releases from WIPP during the Alternative Action 5-126

5.56 Cumulative volume of inflow at 200 years (m^3) for two values of permeability (k) 5-147

5.57 Description of and input parameters for cases analyzed 5-153

5.58 Numerical parameters input to NEFTRAN for Cases IA, IB, and IC 5-159

5.59 Numerical retardation factors input to NEFTRAN for use in Cases IA, IB, and IC 5-160

5.60 Arrival times at intermediate points between the waste disposal rooms and the stock well (years) 5-161

5.61 Maximum dose received by a drilling crew member due to exposure to CH TRU waste-contaminated drilling cuttings 5-164

5.62 Maximum dose received by a drilling crew member due to exposure to RH TRU waste-contaminated drilling cuttings at 100 years after repository closure 5-165

5.63 Committed effective dose equivalent after 1-year exposure (mrem during the subsequent 50 years) CH TRU waste 5-166

5.64 Committed effective dose equivalent after 1-year exposure (mrem during the subsequent 50 years) RH TRU waste 5-166

5.65 Characterization of the waste plume within the Culebra from point of release to stock well 5-173

5.66 Base-case and range of values of parameters describing the brine reservoir 5-176

5.67 Specifications for intrusion borehole for Case II simulations 5-177

5.68 Radionuclide concentrations in the Culebra aquifer at the stock well at 10,000 years 5-178

5.69 Parameter base-case and range values selected for the Culebra Dolomite 5-188

Table | Page

5.70 Maximum 50-year committed doses incurred by an individual eating beef for 1 year that was watered at a stock well tapping a contaminated Culebra aquifer, for six scenarios (mrem during the 50 years following intake) 5-189

5.71 Integrated release at WIPP-site boundary and stock well at 10,000 years, Case IIA (rev) 5-198

5.72 Integrated release at WIPP-site boundary and stock well at 10,000 years, Case IIC (rev) 5-199

5.73 Comparison of preliminary and present estimates of integrated releases 5-200

5.74 Summary of long-term dose commitments for leaving the stored waste in place at INEL, without additional mitigation measures 5-205

5.75 Possible long-term consequences of storage at INEL 5-206

5.76 Summary of consequences from postulated accidents in the Savannah River Site Burial Ground 5-207

6.1 Summarized qualitative description of waste treatment benefits 6-23

10.1 Active Federal permits, approvals, and notifications 10-5

10.2 Active State permits and approvals 10-7

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1.0 PURPOSE AND NEED FOR ACTION

1.1 BACKGROUND

The U.S. Department of Energy (DOE) has recently completed major construction activities at the Waste Isolation Pilot Plant (WIPP) in southeastern New Mexico, 26 mi east of Carlsbad.[1] The surface facilities needed to initiate operations are complete, and most of the underground experimentation rooms and waste rooms for initial waste emplacement have been excavated. Additional waste rooms will be mined in advance of waste emplacement. The WIPP underground facility, which is 2,150 ft below the land surface in a 3,000 ft-thick bedded salt and anhydrite formation, was constructed as a research and development facility to demonstrate the safe disposal of transuranic (TRU) waste from DOE defense facilities. The post-1970 generated TRU waste proposed to be disposed of at the WIPP results primarily from defense-related plutonium reprocessing and fabrication as well as defense-related research activities at DOE facilities. The volumes and characteristics of TRU waste expected to be disposed of at the WIPP are discussed in Subsection 2.3 and Appendix B of this Supplemental Environmental Impact Statement (SEIS).

The WIPP was authorized by the Department of Energy National Security and Military Applications of Nuclear Energy Act of 1980, (Public Law 96-164). This Act provides as follows:

> Not withstanding any other provision of law, the Waste Isolation Pilot Plant is authorized as a defense activity of the Department of Energy . . . for the express purpose of providing a research and development facility to demonstrate the safe disposal of radioactive waste resulting from the defense activities and programs of the United States exempted from regulation by the Nuclear Regulatory Commission.

The Act also requires the DOE to consult and cooperate with the State of New Mexico with respect to public health and safety concerns. This consultation-and-cooperation process is governed by the written agreements discussed in Subsection 10.3.2 of this SEIS. The roles of the State of New Mexico, the Environmental Evaluation Group (EEG) and other agencies and organizations with WIPP overview responsibilities are discussed in Subsection 10.3.

The DOE proposes to begin in 1990 to conduct certain experimental and operational tests in the WIPP during a Test Phase of approximately 5 years. These tests would not begin until 1) the completion of certification that the containers to be used for shipping the TRU waste to the WIPP meet regulatory requirements, (TRUPACT-II was

---

[1] Vertical lines in the margins denote changes to the draft SEIS made in response to comments.

certified by the U.S. Nuclear Regulatory Commission (NRC) for TRU waste transport of contact-handled (CH) TRU waste on August 30, 1989); 2) the receipt of the needed legislative or administrative authority to withdraw public lands for WIPP use; 3) the completion of preoperational readiness analyses; and 4) satisfaction of all applicable environmental requirements, described in Section 10.0.

1.2 NEPA COMPLIANCE

1.2.1 1980 WIPP FEIS

The 1980 WIPP Final Environmental Impact Statement (FEIS) and the associated public review and comment period provided environmental input for the DOE's initial decision to proceed with the WIPP (DOE, 1980). The significance of impacts associated with the various alternatives was assessed. For the selected alternative, a two-phased approach to development was proposed: 1) a site and preliminary design validation (SPDV) program, as discussed in Subsection 8.2.1 of the FEIS, and 2) full construction, as discussed in FEIS Subsection 8.2.2. The durations of key WIPP activities are shown in Figure 1.1.

The 1980 FEIS presented an analysis of the environmental impacts of a number of alternatives for demonstrating the safe disposal of TRU waste. The alternatives considered included:

- Alternative 1. No action. A research and development facility to demonstrate safe disposal of TRU waste would not be developed and post-1970 TRU waste would continue to be retrievably stored.
- Alternative 2. Developing the WIPP at the Los Medanos site in southeastern New Mexico.
- Alternative 3. Disposing of stored TRU waste in the first available repository for high-level radioactive waste.
- Alternative 4. Delaying a decision on the site for a WIPP until at least 1984 to allow for the investigation of alternative sites.

Alternative methods and geologic media for TRU waste disposal were also considered but rejected in the FEIS. The alternative methods included burial in deep ocean sediments, emplacement in deep drillholes, transmutation, and ejection into space. The alternative geologic media included igneous, volcanic, and argillaceous rocks.

The DOE's Record of Decision, published January 28, 1981 (46 FR 9162), announced the DOE's selection of Alternative 2: to proceed with the phased development of the WIPP at the Los Medanos site in southeastern New Mexico. The decision called for the WIPP to be designed to accomodate approximately 6.2 million cubic feet of contact-handled TRU waste and 0.25 million cubic feet of remote-handled TRU waste. The analysis in the supporting FEIS concluded that any adverse environmental impacts of the implementation of Alternative 2 would be generally minor and that the Los Medanos

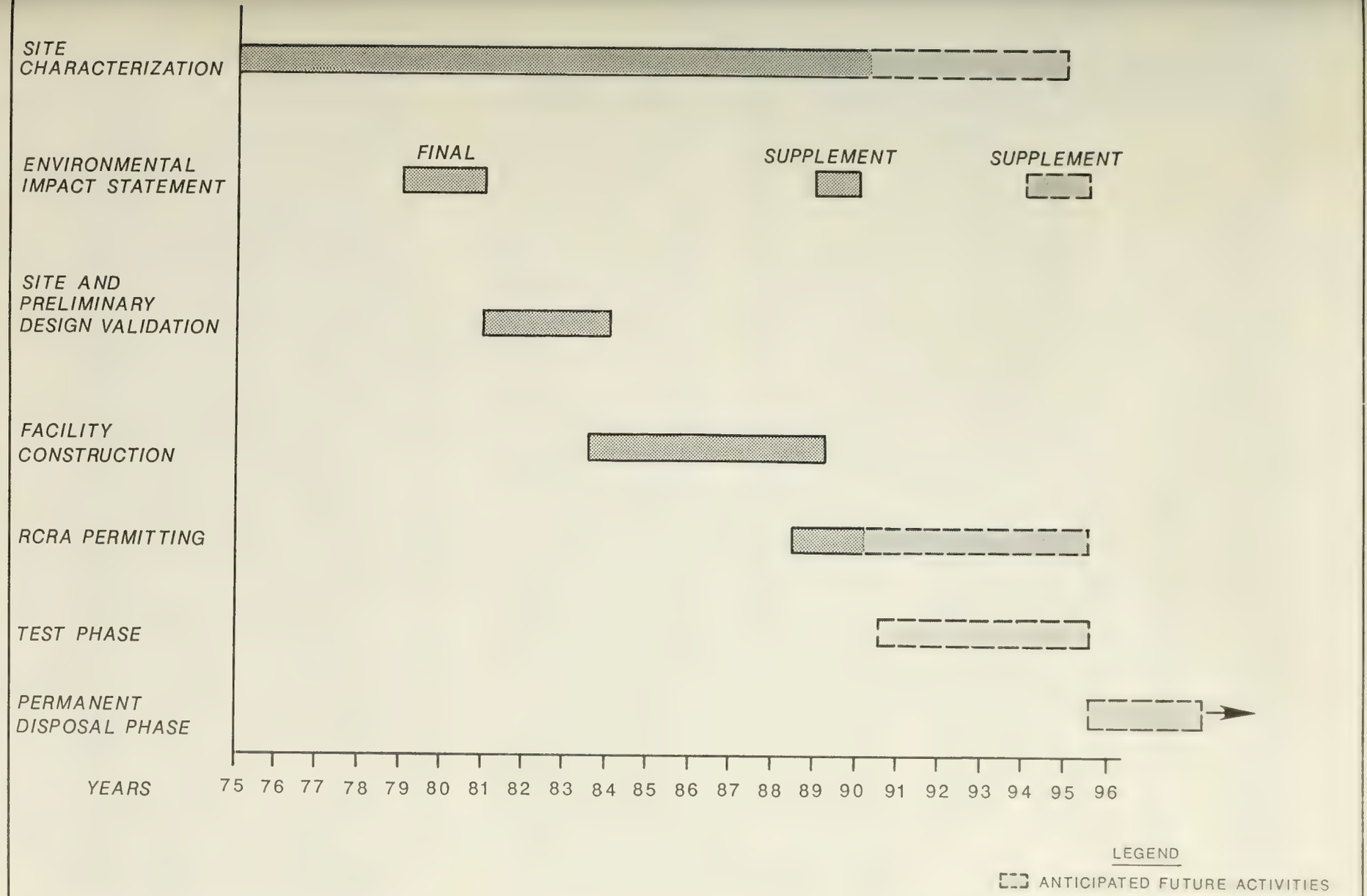

FIGURE 1.1
KEY WIPP ACTIVITIES

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site would be acceptable for the long-term disposal of TRU waste with "minimal risk of any release of radioactivity to the environment" (DOE, 1981). The DOE also concluded that the consequences of the no-action alternative were unacceptable.

1.2.2 NEPA Documentation Since the FEIS

The 1981 Record of Decision stated the following:

> If significant new environmental data results from the SPDV program or other WIPP project activities, the FEIS will be supplemented as appropriate to reflect such data, and this decision to proceed with phased construction and operation of the WIPP facility will be reexamined in the light of that supplemental National Environmental Policy Act (NEPA) review.

The Council on Environmental Quality (CEQ) regulations for implementing NEPA procedures (40 CFR Parts 1500-1508) require supplements to draft and to final environmental impact statements if 1) the agency makes substantial changes in the proposed action relevant to environmental concerns, or 2) there are significant new circumstances or information relevant to environmental concerns that bear on the proposed action or its impacts. Agencies may also prepare supplemental environmental impact statements on their own initiative when "the purposes of the Act (NEPA) will be furthered in doing so" [40 CFR 1502.9(c)].

In April 1982, the DOE prepared an environmental analysis to determine the significance of proposed cost-reduction measures regarding the construction of the WIPP and concluded that the potential environmental impact would not be significant (DOE, 1982).

The DOE performed a similar environmental analysis of the results of the SPDV in 1983 to determine whether the conclusions stated in the Record of Decision remained valid. The DOE determined that "the new information either falls within the bounds of the impacts discussed in the FEIS or represents insignificant change" (DOE, 1983).

1.3 PURPOSE AND NEED FOR SUPPLEMENT TO FEIS

Since the publication of the FEIS in October 1980 and the subsequent Record of Decision to proceed with the phased construction and operation of the WIPP, new geologic and hydrologic information has led to changes in the understanding of the hydrogeologic characteristics of the area as they relate to the long-term performance of the WIPP. In addition, several changes have occurred in the Proposed Action and in the information and assumptions used to calculate the impacts reported in the FEIS. These include changes in the composition of the waste inventory, the transportation of waste to the WIPP, modification of the Test Phase, and the management of TRU mixed waste with hazardous chemical constituents.

This SEIS evaluates the environmental consequences of the Proposed Action as modified since 1980 in light of new information and assumptions. Modifications to the Proposed Action since 1980 that are examined in this SEIS are as follows:

- Changes in the TRU radionuclide inventory, including the identification of high-curie and high-neutron waste and the elimination of experiments with high-level waste (Subsection 3.1.1.1).

- Consideration of the hazardous chemical constituents of TRU mixed waste (Subsection 3.1.1.2).

- Changes in waste transportation including packaging, routes, and modes (Subsection 3.1.1.3).

- Modification of the Test Phase (Subsection 3.1.1.4).

The new data and information and the resulting interpretations principally address the geologic and hydrologic systems at the WIPP site. They include:

- Determination of a locally lower permeability in the Salado Formation, the geologic formation in which the WIPP underground facilities are located (Subsection 4.3.2).

- Determination of a potentially higher moisture content in the Salado Formation and consequent brine inflow (Subsection 4.3.2).

- Discovery of a higher transmissivity zone in the Rustler Formation in the southeastern portion of the WIPP site (Subsection 4.3.3).

- New data leading to a conclusion that "salt creep" (convergence) in the repository occurs faster than previously believed (Subsection 4.3.2).

- Pressurized brines within the Castile Formation which are assumed to be present beneath a portion of the WIPP waste emplacement panels (Subsection 4.3.4.2).

- Discovery of fractures in SPDV rooms (Subsection 4.3.2.4).

In addition, Subsection 5.2.1 and Appendix P provide information that describes the TRU waste retrieval and processing activities at representative DOE generator/storage facilities. This subsection and appendix also provide descriptions of the bin and waste preparation that would occur at the generator/storage facilities prior to the proposed Test Phase. This information has been included to reflect new information and analysis since the 1980 FEIS.

1.4 PROPOSED ACTION

The Proposed Action is to proceed with the phased development and operation of the WIPP as described in the 1980 FEIS and 1981 Record of Decision, as modified by the changes and new information or assumptions listed in Subsection 1.3 above. The next phase in the development of the WIPP project would involve conducting certain experiments and operational demonstrations (i.e., Test Phase). During this Test Phase

(approximately 5 years), experiments would be conducted to reduce the uncertainties associated with the prediction of several processes (e.g., gas generation) that influence repository performance. In addition, operations would be conducted to confirm the TRU waste management system's ability to safely and efficiently certify, package, transport, emplace, and manage waste in the WIPP. The results of the experiments would be used to assess the ability of the WIPP to meet regulatory requirements for the protection of human health and the environment from the disposal of TRU waste.

The elements of the Test Phase, Performance Assessment tests and operations demonstration, continue to evolve. At this time, the Performance Assessment tests would be comprised of laboratory-scale, bin-scale, and alcove-scale tests. Currently, plans on such issues as waste source, type, and volumes for the initial phase of tests are nearing finalization (DOE, 1989a). Waste requirements for the integrated operations demonstration are currently undergoing DOE review. In December 1989, the DOE published a detailed phased plan for the Test Phase (DOE, 1989a; also see Appendix O), that focused on the methods and activities required to demonstrate compliance with the long-term performance standard of 40 CFR 191, Subpart B. In addition, several of the tests planned for hte Test Phase provide data that would be used to support the WIPP's demonstration that there would be no migration of hazardous constituents of the waste, as required under the RCRA Land Disposal Restrictin (40 CFR 268). A separate document would be developed to describe in detail the Integrated Operations Demonstration plan.

If, during the Test Phase, there were significant indications of noncompliance, a number of options would be considered (e.g., waste treatment, engineering modifications) for bringing the WIPP into compliance and the required NEPA documentation for those options would be prepared before a decision to proceed was made. At the conclusion of the Test Phase, the DOE would determine whether the WIPP would comply with the radiation protection standards issued by the U.S. Environmental Protection Agency (EPA) for the disposal of TRU waste (40 CFR Part 191, Subpart B), their RCRA Land Disposal Restrictions (40 CFR Part 268) and any other applicable requirements. If there were a determination of compliance with the EPA standards and other regulatory requirements, and a favorable Record of Decision based on an updated SEIS, the WIPP would move into the Disposal Phase. If it were determined after considering various options that the WIPP could not comply with regulatory requirements, the waste would be retrieved and the WIPP would be decommissioned or put to other uses as appropriate.

The information and analyses in this SEIS are drawn from other WIPP-related documents, including the draft final safety analysis report (DOE, 1989b), the proposed test plan (see Appendix O), the safety analysis report for the TRUPACT-II (DOE, 1989c), and others as referenced throughout this SEIS. Where uncertainties exist in aspects of the Proposed Action, impact analyses provide an "upper bound." For example, the SEIS analyzes the impacts of a Test Phase conducted with a volume of TRU waste that represents up to 10 percent of the total design waste capacity of the WIPP. Although 10 percent has been selected to ensure that the impacts of the Test Phase are "bounded," the amount of TRU waste to be used for the Test Phase is likely to be less. Other examples of such "bounding" include: 1) the use of the design capacity of the WIPP (6.45 M ft^3 TRU waste) rather than more recent, lower volume estimates, 2) shipment of contact-handled (CH) waste from 10 facilities during the Test Phase rather than primarily from two, 3) mode of transport (100 percent truck and maximum train

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   8 245 10   Waste Isolation Pilot Plant : !b draft supplement environmental
impact statement.
   9 260 0    Washington, D.C. : !b U.S. Dept. of Energy, Assistant Secretary
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  15 650  0   Radioactive wastes !x Storage !z New Mexico.
  16 740 01   Waste Isolation Pilot Plant test phase.
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rather than specific combinations of the two modes), and 4) use of maximum curie content in the transportation and operations accident analysis.

The FEIS considered a number of alternatives to the Proposed Action. Two alternatives are considered in this SEIS: 1) no action, and 2) conducting only those tests that can be performed without emplacing waste underground until it is determined that the WIPP complies with the EPA standards and other regulatory requirements for the long-term protection of the environment from the disposal of TRU waste.

1.5 CONTENT OF THE SEIS

This final SEIS is comprised of 13 volumes: Volume 1 contains the text; Volume 2 contains supporting appendices; Volume 3 contains the responses to public comments on the draft SEIS; Volumes 4 and 5 contain the indices for Volumes 6 through 13, and Volumes 6-13 contain reproductions of all transcripts, letters, and exhibits received during the public comment period.

Volume 1 is divided into 10 major sections, summarized as follows:

- Section 1, Purpose and Need for Action. This section provides historical background on the Proposed Action.

- Section 2, Background: An Overview of the WIPP. This section presents a description of the WIPP as it currently exists.

- Section 3, Description of the Proposed Action and Alternatives. The Proposed Action is to proceed with the development and operation of the WIPP as described in the FEIS and as modified by changes described in this SEIS. There are two alternatives to the Proposed Action, the No Action Alternative and an alternative action involving bin-scale tests at a location other than the WIPP underground.

- Section 4, Description of the Existing Environment at the WIPP Site. This section summarizes and updates the description of the existing environment provided in the FEIS. The new understanding of the hydrogeologic system at the WIPP site is highlighted in Subsections 4.2 and 4.3.

- Section 5, Environmental Consequences. This section presents analyses of postulated radionuclide and hazardous chemical releases and exposures, and the consequences resulting both from routine transportation and operations and from transportation or operational accidents. Subsection 5.4 addresses decommissioning and long-term repository performance.

- Section 6, Mitigation Measures. This section summarizes the mitigation measures discussed in the FEIS and discusses the mitigation measures that have been implemented in support of WIPP construction activities or that may be implemented to minimize potential adverse environmental impacts of the WIPP.

- Section 7, Unavoidable Adverse Impacts. This section briefly reiterates the findings included in the FEIS and presents new findings.

- Section 8, Short-Term Uses and Long-Term Productivity. This section briefly reiterates the findings included in the FEIS and presents new findings.

- Section 9, Irreversible and Irretrievable Commitments of Resources. This section briefly reiterates the findings included in the FEIS and presents new findings.

- Section 10, Environmental Regulatory Requirements and Oversight Organizations. This section discusses additional regulatory requirements since the FEIS, including the applicable Resource Conservation and Recovery Act (RCRA) requirements and the EPA environmental protection standards for the management and disposal of TRU waste. It also contains a discussion of WIPP oversight organizations.

The FEIS has been reprinted and distributed with the draft SEIS to the public and reviewing agencies as background to the SEIS. Additionally, copies of the SEIS and the FEIS have been placed in designated DOE reading rooms and public libraries. A list of these locations is provided in Appendix K. Copies of key documents referenced in the SEIS are available in the designated DOE reading rooms. The SEIS employs cross-referencing to the FEIS and referencing of other relevant material as provided by 40 CFR 1502.21. This cross-referencing reduces the document's length, enhances readability, and avoids unnecessary redundancy.

Table 1.1 cross-references the environmental topics addressed in the FEIS and the SEIS and lists the sections in the FEIS that have not changed significantly. To the extent possible, the SEIS has remained consistent with the FEIS by employing English units of measurement for commonly used units and metric units for more technical subject areas as appropriate.

1.6 OVERVIEW OF PUBLIC PARTICIPATION AND INTERGOVERNMENTAL AFFAIRS

Prior to the preparation of this SEIS, the DOE briefed representatives of 21 State governments, 5 Congressional delegations, key Congressional committees and subcommittees, various Indian nations, and environmental groups regarding the SEIS and related issues and sought input from these groups on key issues that should be addressed in the SEIS. These briefings are described in greater detail in Appendix H. The draft SEIS was issued April 21, 1989, and at that time a 90-day comment period began. During the 90-day comment period, the DOE held 12 days of public hearings in nine locations: Atlanta, Georgia; Pocatello, Idaho; Denver, Colorado; Pendleton, Oregon; Albuquerque, New Mexico (2 days); Santa Fe, New Mexico (3 days); Artesia, New Mexico; Odessa, Texas; and Ogden, Utah. Approximately 1,000 individuals testified. Transcripts of the hearing testimonies, exhibits and written comments received on the draft SEIS have been reprinted in Volumes 6 through 13. During the comment

period, the DOE also held two public information meetings on the WIPP project and draft SEIS in Roswell and Carlsbad, New Mexico.

The Bureau of Land Management (BLM) is a cooperating agency in support of the SEIS in accordance with 40 CFR 1501.6. Comments obtained during public hearings, as well as all other public (including written) comments submitted to the DOE on the draft SEIS, were provided to the BLM.

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TABLE 1.1 Cross-references between the FEIS and the SEIS by section number

FEIS Section		SEIS Section	
1	SUMMARY	SUMMARY	
1.1	Background		Purpose and Need
1.2	Alternatives		Background
1.3	The Los Medanos Site		Description of Alternatives
1.4	Environmental Evaluation of Alternatives		Existing Environment
1.5	Conclusions		Not addressed; conclusions will be documented in the Record of Decision
2	BACKGROUND	1.0	PURPOSE AND NEED FOR ACTION
2.1	Brief Introduction to this Document	1.1	Background
		1.2	NEPA Compliance
		1.3	Purpose and Need for Supplement to FEIS
		1.4	Proposed Action
		1.5	Content of the SEIS
		1.6	Overview of Public Participation and Intergovernmental Affairs
2.2	Waste-Management Programs Leading to the Consideration of the Los Medanos Site		Further discussion in this SEIS is unnecessary
2.3	Defense Transuranic Waste	2.3	Waste Types and Forms
		3.1.1	Changes to the Proposed Action and New Information or Circumstances
		App. A	Waste Isolation Pilot Plant Waste Acceptance Criteria
		App. B	Waste Characteristics
3	DEVELOPMENT OF ALTERNATIVES	3.0	DESCRIPTION OF THE PROPOSED ACTION AND ALTERNATIVES

TABLE 1.1 Continued

FEIS Section		SEIS Section	
3.1	The Alternative of No Action	3.2.1	No Action Alternative
3.2	Alternative Disposal Methods		Further discussion in this SEIS is unnecessary
3.3	Alternatives for Geologic Disposal		Further discussion in this SEIS is unnecessary
3.4	Alternative Areas in Bedded Salt		Further discussion in this SEIS is unnecessary
3.5	Alternative Sites in Alternative Media		Further discussion in this SEIS is unnecessary
3.6	Formulation of Alternatives	3.2.2	Alternative Action
		3.3	Alternatives not Considered in Detail
4	ENVIRONMENTAL IMPACTS OF ALTERNATIVES	5.0	ENVIRONMENTAL CONSEQUENCES
4.1	Alternative 1: No Action	5.5	No Action Alternative
4.2	Alternative 2: The Authorized WIPP Facility	5.1	Environmental Impacts of Implementation of FEIS Selected Alternative
		5.2	Environmental Impacts of SEIS Proposed Action
		5.4	Decommissioning and Long-Term Performance
		App. D	Transportation and Transportation-Related Risk Assessments
		App. F	Radiological Release and Dose Modeling for Permanent Disposal Operations
		App. G	Toxicity Profiles, Risk Assessment Methodology, and Models for Chemical Hazards
		App. I	Methods and Data Used in Long-Term Consequence Analyses
		App. N	Re-evaluation of Radiation Risks from WIPP Operations
4.3	Alternative 3: The Preferred Alternative: Combine the Authorized WIPP Activities with the First Available High-Level-Waste Repository		Further discussion in this SEIS is unnecessary
4.4	Alternative 4: A Defense-Waste Facility Built After the Consideration of Sites in Addition to Los Medanos		Further discussion in this SEIS is unnecessary

(Continued)

LIBRARY U. OF I. URBANA-CHAMPAIGN

TABLE 1.1 Continued

FEIS Section		SEIS Section	
4.5	Tabular Comparison of Alternatives		Executive Summary, Table S-1
5	WASTE FORMS	2.3	Waste Types and Forms
		App. B	Waste Characteristics
5.1	Waste-Acceptance Criteria	2.3.1	Waste Acceptance Criteria (WAC)
		App. A	Waste Isolation Pilot Plant Waste Acceptance Criteria
5.2	Acceptance Criteria Assumed for Analyses Reported in This Document	2.3.1	Waste Acceptance Criteria (WAC)
		App. A	Waste Isolation Pilot Plant Waste Acceptance Criteria
5.3	Processing of Transuranic Waste	2.3.2	Processing of TRU Waste
		App. P	TRU Waste Retrieval, Handling, and Processing
6	TRANSPORTATION OF WASTE TO THE WIPP		
6.1	Regulations	3.1.1.3	Transportation of TRU Waste to the WIPP
		10.2.1	Resource Conservation and Recovery Act of 1976
		10.2.5	Nuclear Regulatory Commission (NRC) TRUPACT-II Certification
		10.2.6	Transportation Regulations
		App. D	Transportation and Transportation-Related Risk Assessments
		App. L	Containers and Casks for Shipping TRU Wastes
		App. M	Summary of the Management Plan for the Trucking Contractor

(Continued)

(Continued)

FEIS Section		SEIS Section	
6.2	Organizations Responsible for Regulating Transportation	3.1.1.3	Transportation of TRU Waste to the WIPP
		10.2.6	Transportation Regulations
		App. D	Transportation and Transportation-Related Risk Assessments
		App. L	Containers and Casks for Shipping TRU Wastes
		App. M	Summary of the Management Plan for the Trucking Contractor
6.3	Packages and Packaging Systems	3.1.1.3	Transportation of TRU Waste to the WIPP
		App. D	Transportation and Transportation-Related Risk Assessments
		App. L	Containers and Casks for Shipping TRU Wastes
6.4	Routes	3.1.1.3	Transportation of TRU Waste to the WIPP
		App. D	Transportation and Transportation-Related Risk Assessments
6.5	Volumes of Waste and Number of Shipments	3.1.1	Changes to the Proposed Action and New Information or Circumstances
		App. B	Waste Characteristics
		App. D	Transportation and Transportation-Related Risk Assessments
6.6	Cost of Transporting Contact-Handled TRU Waste to the WIPP		Further discussion in this SEIS is not necessary
6.7	Radiological Impacts of Waste Transport Under Normal Conditions	5.2.2, 5.3.7	Transportation
		App. D	Transportation and Transportation-Related Risk Assessments
6.8	Radiological Impacts of Waste Transport Under Accident Conditions	5.2.2, 5.3.7	Transportation
		App. D	Transportation and Transportation-Related Risk Assessments
6.9	Nonradiological Impacts of Waste Transport Under Accident Conditions	5.2.2, 5.3.7	Transportation
		App. D	Transportation and Transportation-Related Risk Assessments

LIBRARY OF THE URBANA-CHAMPAIGN

TABLE 1.1 Continued

FEIS Section		SEIS Section	
6.10	Intentional Destructive Acts		Further discussion in this SEIS is not necessary
6.11	Emergency Procedures	2.8	Transportation Emergency Planning
		App. C	Transportation Emergency Planning
		App. M	Summary of the Management Plan for the Trucking Contractor
6.12	Financial Responsibility for Accidents	App. C	Transportation Emergency Planning
		App. D	Transportation and Transportation-Related Risk Assessments
7	THE LOS MEDANOS SITE AND ENVIRONMENTAL INTERFACES	4.0	DESCRIPTION OF THE EXISTING ENVIRONMENT AT THE WIPP SITE
7.1	Biophysical Environment	4.1	Existing Environment at the WIPP Site
7.2	Sociocultural Environment	4.1.2	Socioeconomic Environment
7.3	Geology	4.2	Geology
		App. E	Hydraulic and Geotechnical Measurements at the WIPP Horizon
7.4	Hydrology	4.3	Hydrology and Water Quality
		App. E	Hydraulic and Geotechnical Measurements at the WIPP Horizon
8	THE WIPP AND ITS OPERATION	2.0	BACKGROUND: AN OVERVIEW OF THE WIPP
8.1	Description and Use of the Site	2.1	Location
8.2	General Description of the WIPP	2.0	BACKGROUND: AN OVERVIEW OF THE WIPP

(Continued)

TABLE 1.1 Continued

FEIS Section		SEIS Section	
8.3	Surface Facilities and Operations	2.2.1	Surface Facilities
		2.4	Waste Receipt and Emplacement
		2.5	Waste Retrieval at the WIPP
8.4	Underground Facilities and Operations	2.2.2	Underground Facilities
		2.4	Waste Receipt and Emplacement
		2.5	Waste Retrieval at the WIPP
8.5	Systems for Handling Radioactive Waste Generated at the Site		Not readdressed; FEIS discussion is still relevant and current
8.6	Sources of the Potential Release of Radioactive Materials		Not readdressed; FEIS discussion is still relevant and current
8.7	Nonradioactive Waste	5.2.4	Risk Assessment and Analysis of Hazardous Chemical Environmental Consequences of Operations and Possible Retrieval of Waste at the WIPP
		App. G	Toxicity Profiles, Risk Assessment Methodology, and Models for Chemical Hazards
8.8	Auxiliary Systems		Not readdressed; FEIS discussion is still relevant and current
8.9	Research and Development Program	3.1.1.4	Implementation of a Modified Test Phase
		App. O	Test Plan Summary
8.10	Plans for Retrieval	2.5	Waste Retrieval at the WIPP
8.11	Plans for Decommissioning	2.6	Plans for Decommissioning
8.12	Emergency Planning, Security, and Safeguards	2.7	Site Emergency Planning and Security
9	ANALYSIS OF THE ENVIRONMENTAL IMPACTS OF THE WIPP	5.0	ENVIRONMENTAL CONSEQUENCES
9.1	Actions Affecting the Environment	5.1	Environmental Impacts of Implementation of FEIS Selected Alternative

(Continued)

LIBRARY OF THE UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

TABLE 1.1 Continued

FEIS Section		SEIS Section	
9.2	Effects During Site Preparation and Construction	5.1	Environmental Impacts of Implementation of FEIS Selected Alternative
9.3	Effects of Plant Operation	5.2	Environmental Impacts of SEIS Proposed Action
9.4	Economic and Social Effects of Plant Construction and Operation	5.1.2	Socioeconomics
9.5	Environmental Effects of Accidents During Operation	5.2.3	Risk Assessment and Analysis of Radiological Environmental Consequences of Operations and Possible Retrieval of waste at the WIPP
		5.2.4	Risk Assessment and Analysis of Hazardous Chemical Environmental Consequences of Operations and Possible Retrieval of Waste at the WIPP
		5.3.8	Radiological Assessment: Operations
		5.3.9	Chemical Assessment: Operations
		App. F	Radiological Release and Dose Modeling for Permanent Disposal Operations
		App. G	Toxicity Profiles, Risk Assessment Methodology, and Models for Chemical Hazards
		App. N	Re-evaluation of Radiation Risks from WIPP Operations
9.6	Mitigation of Impacts	6.0	MITIGATION MEASURES
9.7	Long-Term Effects	5.4	Decommissioning and Long-Term Performance
		App. I	Methods and Data Used in Long-Term Consequence Analyses

TABLE 1.1 Continued

FEIS Section		SEIS Section	
9.8	Effects of Removing the TRU Waste Stored at Idaho	5.2.1	Waste Retrieval, Handling, and Processing at DOE Facilities
		App. P	TRU Waste Retrieval, Handling, and Processing
10	UNAVOIDABLE ADVERSE IMPACTS	7.0	UNAVOIDABLE ADVERSE IMPACTS
10.1	Construction	7.1	Construction
10.2	Operation	7.2	Operation
10.3	Long-Term Impacts	7.3	Impacts After Decommissioning
10.4	Comparison of Alternatives	7.4	Comparison of Alternatives
11	IRREVERSIBLE AND IRRETRIEVABLE COMMITMENTS OF RESOURCES	9.0	IRREVERSIBLE AND IRRETRIEVABLE COMMITMENTS OF RESOURCES
11.1	Land Use		Further discussion in this SEIS is unnecessary
11.2	Denial of Mineral Resources		Further discussion in this SEIS is unnecessary
11.3	Resources for WIPP Construction	9.1	Construction
11.4	Resources for WIPP Operation	9.2	Operation
11.5	Resources Used at the Idaho National Engineering Laboratory		Further discussion in this SEIS is unnecessary
11.6	Comparison of Alternatives	9.1	Construction
		9.2	Operation
12	RELATION TO LAND-USE PLANS, POLICIES, AND CONTROLS		Not readdressed; FEIS discussion is still relevant and current
12.1	Existing Land-Use Plans, Policies, and Controls		Not readdressed; FEIS discussion is still relevant and current
12.2	Compatibility of the WIPP Project with Existing Land-Use Plans		Not readdressed; FEIS discussion is still relevant and current

(Continued)

LIBRARY OF THE UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

TABLE 1.1 Continued

FEIS Section	SEIS Section	
12.3 Comparison of Alternatives		Not included in this SEIS
13 RELATIONSHIP BETWEEN SHORT-TERM USES AND LONG-TERM PRODUCTIVITY	8.0	SHORT-TERM USES AND LONG-TERM PRODUCTIVITY
14 ENVIRONMENTAL PERMITS, APPROVALS, CONSULTATIONS, AND COMPLIANCES	10.0	ENVIRONMENTAL REGULATORY REQUIREMENTS AND OVERSIGHT ORGANIZATIONS
14.1 Introduction	10.0	ENVIRONMENTAL REGULATORY REQUIREMENTS AND OVERSIGHT ORGANIZATIONS
	10.1	Regulatory Compliance Commitment and Strategy
14.2 Federal and State Permits and Approvals	10.2	Permits and Approvals
14.3 Consultations	10.3	Oversight Organizations
14.4 Public Participation	App. H	Public Information and Intergovernmental Affairs
15 PUBLIC AND AGENCY COMMENTS	Vol 3	Public Comments and Responses
App. A Alternative Geologic Environments		Not readdressed; further discussion in this SEIS is unnecessary
App. B The National Waste Terminal Storage Program and Alternative Geologic Regions		Not readdressed; further discussion in this SEIS is unnecessary
App. C President Carter's Message to Congress on the Management of Radioactive Waste and the Findings and Recommendations of the Interagency Review Group on Nuclear Waste Management		Not readdressed; further discussion in this SEIS is unnecessary
App. D Selection Criteria for the WIPP Site		Not readdressed; further discussion in this SEIS is unnecessary
App. E Descriptions of Waste Types	2.3	Waste Types and Forms
	App. B	Waste Characteristics
	3.1.1	Changes to the Proposed Action and New Information or Circumstances

(Continued)

TABLE 1.1 Continued

FEIS Section	SEIS Section	
App. F Incineration and Immobilization Processes	6.4	Mitigation by Waste Treatment
App. G Methods Used To Calculate Radiation Doses from Radionuclide Releases During Operation	App. F	Radiological Release and Dose Modeling for Permanent Disposal Operations
	App. G	Toxicity Profiles, Risk Assessment Methodology, and Models for Chemical Hazards
	App. N	Re-evaluation of Radiation Risks from WIPP Operations
App. H Description of the Los Medanos Site		Not readdressed; FEIS discussion is still relevant
App. I Correspondence on Archaeology, Historic Sites, Prime Farm Land, and Endangered Species	4.1.1	Biological Environment
	4.1.4, 5.1.3	Land Use
	4.1.6, 5.1.5	Cultural Resources
App. J Effluent and Environmental Measurements and Monitoring Programs	2.9	Environmental Monitoring Programs
App. K Methods Used in Long-Term Safety Analyses	App. I	Methods and Data used in Long-Term Consequence Analyses
App. L An Outline of the Input-Output Model and Impact Projections Methodology		Not readdressed in this SEIS
App. M Socioeconomic Effects of Plant Construction and Operation: Supporting Data		Not readdressed in this SEIS
App. N Effects of Leaving the TRU Waste at Idaho		Not readdressed; FEIS discussion is still relevant
App. O Interpretation of the Radiation Doses Predicted in this Document	App. F	Radiological Release and Dose Modeling for Permanent Disposal Operations
	App. I	Methods and Data Used in Long-Term Consequence Analyses

(Continued)

LIBRARY OF THE UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

TABLE 1.1 Continued

FEIS Section		SEIS Section
App. P Comments from Federal and State Agencies on the Draft Environmental Impact Statement for the Waste Isolation Pilot Plant	Vol. 3	Public Comments and Responses
App. Q Report of the Hearings Panel on the Draft Environmental Impact Statement on the Waste Isolation Pilot Plant		Not applicable to this SEIS

REFERENCES FOR SECTION 1

DOE (U.S. Department of Energy), 1989a. Draft Plan for the Waste Isolation Pilot Plant Test Phase: Performance Assessment and Operations Demonstration, DOE/WIPP 89-011, Carlsbad, New Mexico.

DOE (U.S. Department of Energy), 1989b, June. Final Safety Analysis Report, Waste Isolation Pilot Plant, Carlsbad, New Mexico, draft, WP02-9, Rev. 0, Carlsbad, New Mexico.

DOE (U.S. Department of Energy), 1989c. Safety Analysis Report for the TRUPACT-II Shipping Package, Rev. 2, Docket No. 71-9218, prepared for the U.S. Department of Energy, Nuclear Packaging, Inc., Federal Way, Washington.

DOE (U.S. Department of Energy), 1988a. Environmental Assessment, Management Activities for Retrieved and Newly-generated Transuranic Waste, Savannah River Plant, DOE/EA-0315.

DOE (U.S. Department of Energy), 1988b. Long Range Master Plan for Defense Transuranic Waste Program, DOE/WIPP 88-028.

DOE (U.S. Department of Energy), 1987a. Integrated Data Base for 1987: Spent Fuel and Radioactive Waste Inventories, Projects and Characterizations, DOE/RW-0006, Revision 3.

DOE (U.S. Department of Energy), 1987b. Final Environmental Impact Statement, Disposal of Hanford Defense High-Level, Transuranic and Tank Wastes, Hanford Site, Richland, Washington, Vols. 1-5, DOE/EIS-0113.

DOE (U.S. Department of Energy), 1983. "National Environmental Policy Act (NEPA) Review of the Waste Isolation Pilot Plant (WIPP) Site and Preliminary Design Validation (SPDV) Program," letter dated June 28, 1983, from William A. Vaughan (Assistant Secretary, Environmental Protection, Safety, and Emergency Preparedness) to Herman E. Roser (Assistant Secretary for Defense Programs).

DOE (U.S. Department of Energy), 1982. "Review of the Environmental Analysis for the Cost Reduction Proposal for the WIPP Project," letter dated July 8, 1982, William A. Vaughan (Assistant Secretary, Environmental Protection, Safety, and Emergency Preparedness) to Herman E. Roser (Assistant Secretary for Defense Programs).

DOE (U.S. Department of Energy), 1981. "Waste Isolation Pilot Plant (WIPP): Record of Decision," Federal Register, Vol. 46, No. 18, p. 9162, January 28, 1981 (46 FR 9162).

DOE (U.S. Department of Energy), 1980. Final Environmental Impact Statement, Waste Isolation Pilot Plant, Vols. 1 and 2, DOE/EIS-0026, Washington, D.C.

2.0 BACKGROUND: AN OVERVIEW OF THE WIPP

This section provides an overview of the WIPP as it is currently constructed, the types and forms of waste that may be emplaced in the WIPP, the WIPP Waste Acceptance Criteria (WAC), and the control zones and area boundaries involved in the WIPP project.[1] The construction of the WIPP, planning for decommissioning, and emergency preparedness and response planning have proceeded since the FEIS. Also, several environmental monitoring programs have been undertaken since the FEIS. These programs are described in Subsection 2.9 and their results are summarized in Section 4.

2.1 LOCATION

The WIPP site is located in Eddy County in southeastern New Mexico (Figure 2.1) (FEIS Subsection 8.1). The site is approximately 26 miles east of Carlsbad in an area known as Los Medanos (which translates as "the dunes"), a relatively flat, sparsely inhabited plateau with little surface water and limited land uses. The land is now owned by the Federal government and administered by the Bureau of Land Management (BLM). The land is primarily used for grazing. Other land in the area around the WIPP is used for potash mining and oil and gas exploration and development.

In 1980, the WIPP site consisted of Control Zones I through IV (Figure 2.2). Control Zones I through III consisted of portions of 14 sections of BLM land and two sections of State land in Township 22 South, Range 31 East. Portions of an additional 20 sections were included in Control Zone IV. All 36 sections were to be under full control of the DOE. Zone I included all surface facilities, Zone II defined the maximum extent of underground activities, Zone III provided a 1-mile buffer area around Zone II, and Zone IV represented the area where the DOE would control access to resources. Grazing was to be allowed in Zones II through IV, but mining and drilling activities, as well as habitation, were to be controlled by the DOE.

Control Zones I, II, and III have not changed since the 1980 FEIS, but the DOE has since eliminated the requirement to control the land identified as Control Zone IV. Reduction of the WIPP control area allowed resources beneath this area to become more accessible relative to the analysis presented in the FEIS. As a result, 71 percent of the denied sylvite resources, 65 percent of the denied langbeinite resources, and 57 percent of the crude oil, natural gas, and distillate resources became available.

The WIPP site land withdrawal boundary (Figure 2.2a) lies between the boundaries of existing Control Zone III and former Control Zone IV. This boundary extends at least 1 mile beyond any WIPP underground development and is defined on the surface by

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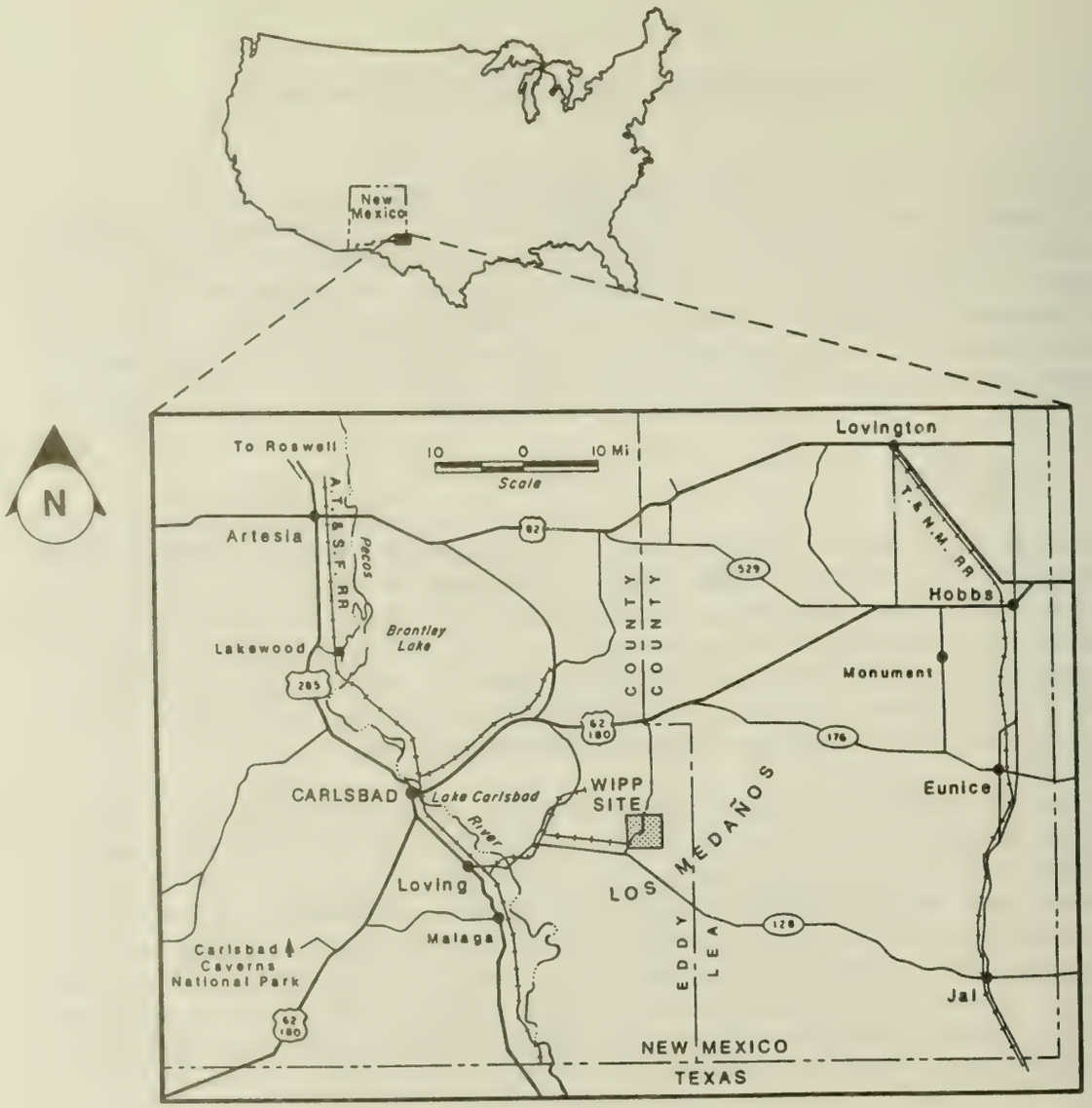
[1] Vertical lines in the margins denote changes to the draft SEIS made in response to comments.



REF: DOE, 1980.

FIGURE 2.1
LOCATION OF THE WIPP SITE

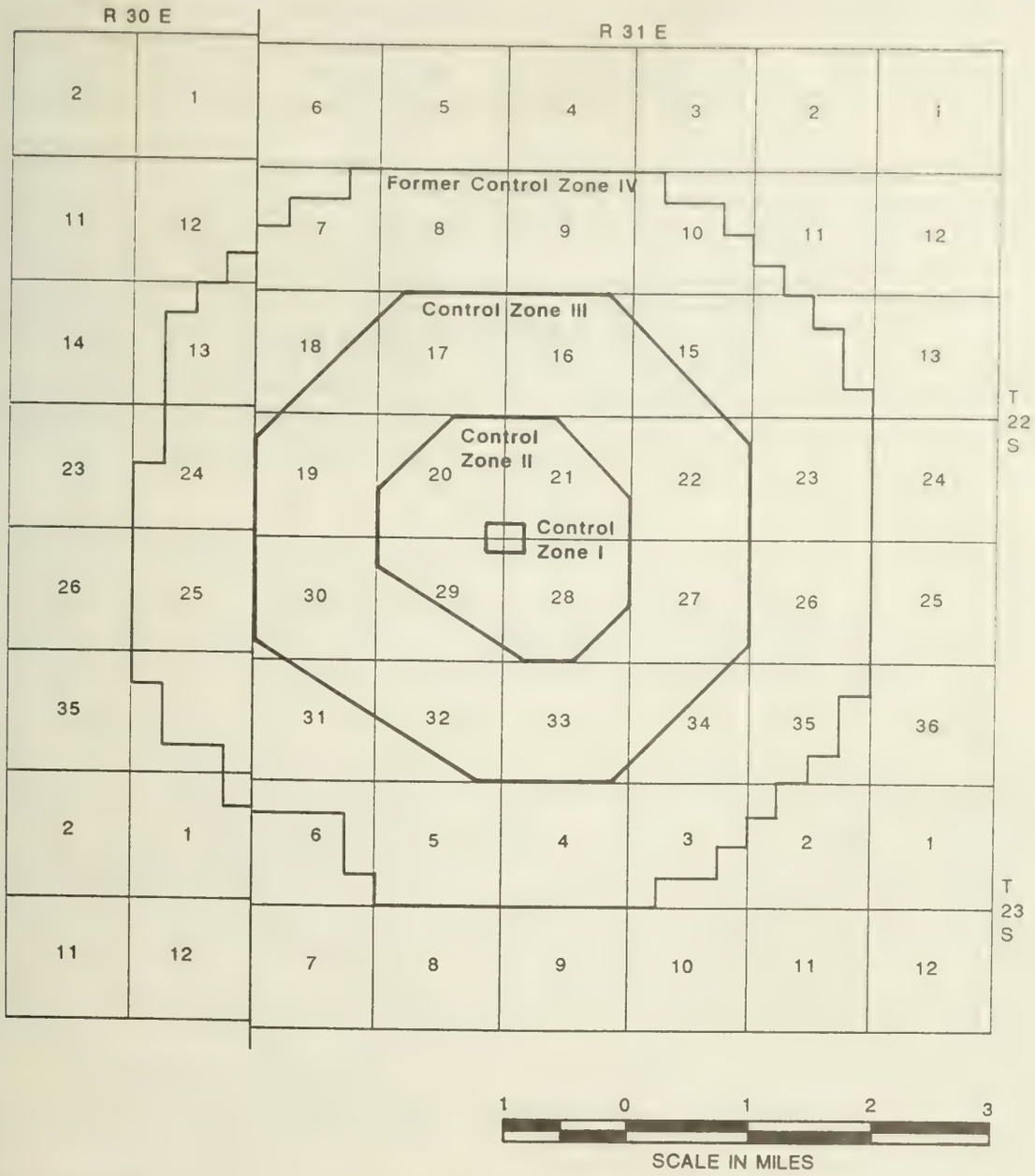


FIGURE 2.2
CONTROL ZONES AT THE WIPP SITE

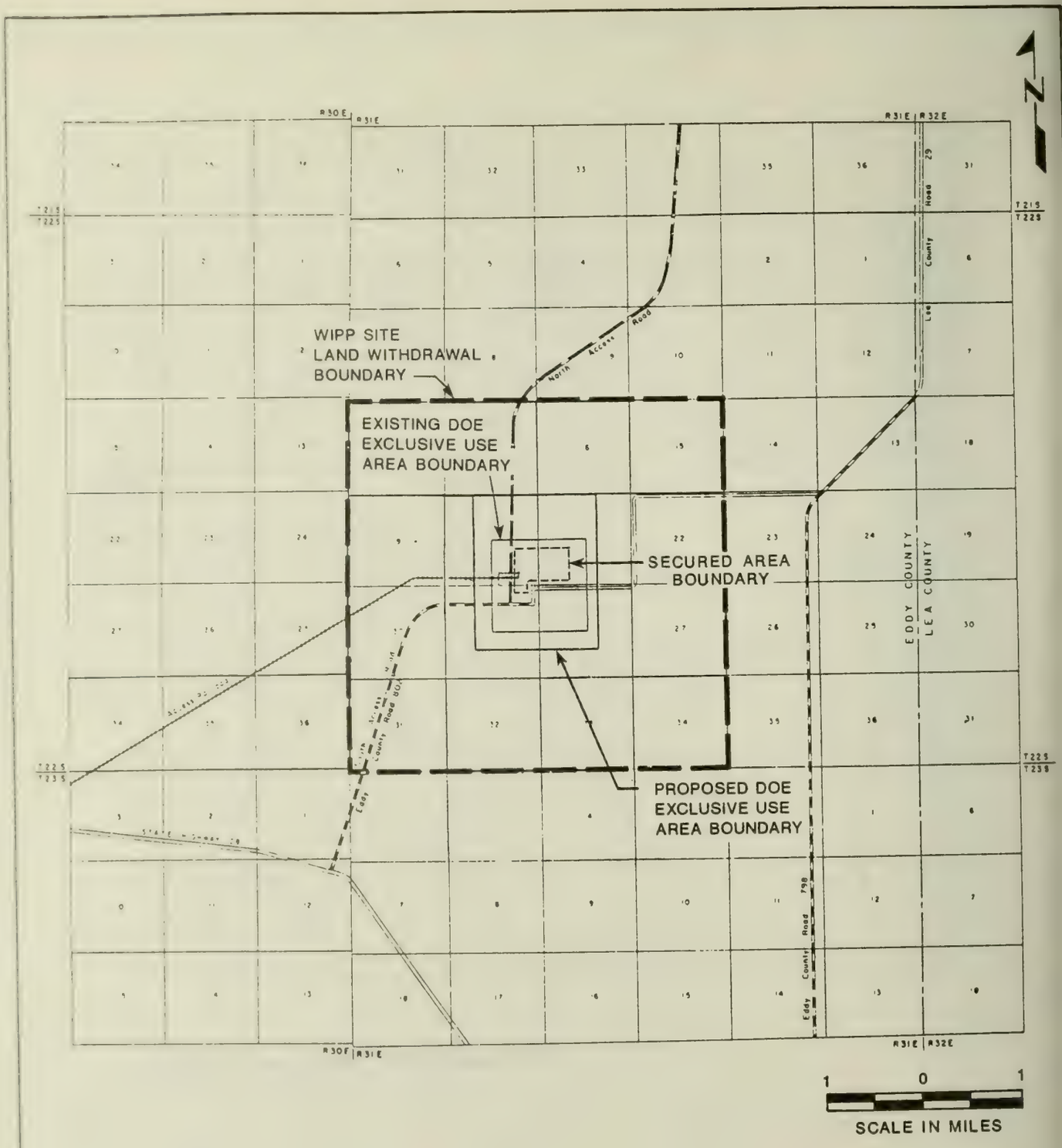


FIGURE 2.2a
WIPP SITE LAND WITHDRAWAL BOUNDARY

the BLM-controlled 16-section land withdrawal area. The land within the WIPP site withdrawal boundary is currently withdrawn from settlement, sale, location, or entry under the general land laws, including mining laws, by the public land order. Grazing allotments under the Taylor Grazing Act have continued under the present land withdrawal, to the extent they are compatible with the WIPP activities.

The WIPP site land withdrawal boundary includes the Secured Area and the DOE Exclusive Use Area (Figure 2.2a). The Secured Area is fenced with barbed wire and contains approximately 250 acres with restricted access. Existing Control Zone I (approximately 35 acres) is within the Secured Area. The DOE Exclusive Use Area currently contains 640 acres under the exclusive control of the DOE. The boundary of this area is between the boundaries of the Secured Area and existing Control Zone II. The DOE has proposed to expand the Exclusive Use Area to contain 1,454 acres to upgrade WIPP site security and this area would be fenced. The boundary of the new DOE Exclusive Use Area would then lie between the boundaries of existing Control Zones II and III.

2.2 FACILITIES

The WIPP includes surface and underground facilities that would support waste handling and emplacement tasks. These facilities, discussed in Subsections 8.2, 8.3, and 8.4 of the FEIS, have been constructed and are briefly described here.

2.2.1 Surface Facilities

The principal surface structure at the WIPP is the waste handling building (Figure 2.3), which includes areas for the receipt, inventory, inspection, and transfer of CH and remote-handled (RH) transuranic (TRU) waste through separate entrances to a common waste shaft (FEIS Subsections 8.2 and 8.3). It also houses offices, change rooms, a health physics laboratory, and equipment for ventilation and filtration. Safety equipment and mechanisms for controlling radiation exposure are included in the building.

Other surface facilities constructed include:

- Exhaust filter building
- Various warehouse buildings and trailers
- Water pump house
- Support building
- Construction management and maintenance complex
- Safety and emergency services building
- TRUPACT-II maintenance building (attached to the waste handling building)
- Guard and security building.

The safety and emergency services building provides housing for the environmental, safety, and health personnel and an indoor garage for site emergency vehicles. Maintenance on the Transuranic Package Transporter Type B shipping containers (TRUPACT-IIs) would be conducted at the TRUPACT maintenance facility, which is adjacent to the waste handling building.

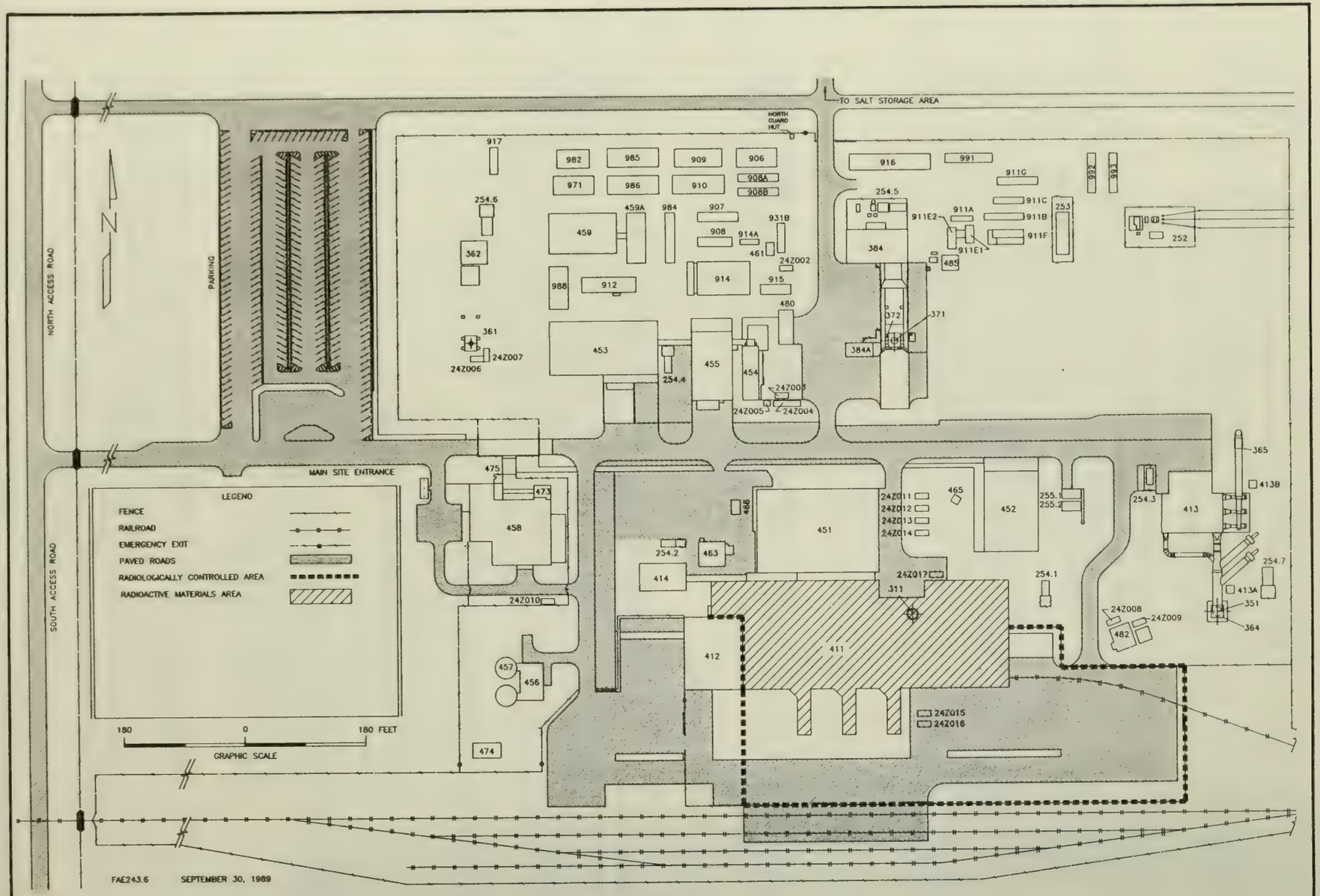


FIGURE 2.3
SURFACE FACILITIES AT THE WIPP

FACILITIES, USAGE AND STRUCTURE NUMBERS (FY 1989)

SPS UTILITY SUBSTATION	FAC 252
13.8 KV SWITCHGEAR 25P-SWG15/1	FAC 253
AREA SUBSTATION NO.1 25P-SW15.1	FAC 254.1
AREA SUBSTATION NO.2 25P-SW15.2	FAC 254.2
AREA SUBSTATION NO.3 25P-SW15.3	FAC 254.3
AREA SUBSTATION NO.4 25P-SW15.4	FAC 254.4
AREA SUBSTATION NO.5 25P-SW15.5	FAC 254.5
AREA SUBSTATION NO.6 25P-SW15.6	FAC 254.6
AREA SUBSTATION NO.7 25P-SW15.7	FAC 254.7
EMERGENCY GENERATOR #1 25-PE 503	FAC 255.1
EMERGENCY GENERATOR #2 25-PE 504	FAC 255.2
WASTE SHAFT	FAC 311
EXHAUST SHAFT	FAC 351
AIR INTAKE SHAFT	FAC 361
AIR INTAKE SHAFT/WINCH HOUSE	FAC 362
EFFLUENT MONITORING INSTRUMENT SHED - "A"	FAC 364
EFFLUENT MONITORING INSTRUMENT SHED - "B"	FAC 365
SALT HANDLING SHAFT	FAC 371
SALT HANDLING SHAFT HEADFRAME	FAC 372
SALT HANDLING SHAFT HOISTHOUSE	FAC 384
UNDERGROUND SERVICES OFFICE	FAC 384A
WASTE HANDLING BUILDING	BLD 411
TRUPACT MAINTENANCE BUILDING	BLD 412
EXHAUST SHAFT FILTER BUILDING	BLD 413
MONITORING STATION A	BLD 413A
MONITORING STATION B	BLD 413B
WATER CHILLER FACILITY	FAC 414
SUPPORT BUILDING - OFFICES, ETC.	BLD 451
SAFETY & EMERGENCY SERVICES FACILITIES	BLD 452
WAREHOUSE/SHOPS BUILDING	BLD 453
VEHICLE SERVICE BUILDING	BLD 454
AUXILIARY WAREHOUSE BUILDING - MAINTENANCE	BLD 455
WATER PUMPHOUSE	BLD 456
WATER TANKS (2)	FAC 457
GUARD AND SECURITY BUILDING	BLD 458
CORE STORAGE BUILDING	BLD 459
DBL. WIDE TRAILER - OFFICE	BLD 459A
MAINTENANCE STORAGE	BLD 461
COMPRESSOR BUILDING	BLD 463
AUXILIARY AIR INTAKE	FAC 465
TELEPHONE HUT	BLD 468
ARMORY BUILDING - ARMORY AND LOCK SHOP	BLD 473
HAZARDOUS WASTE STORAGE BUILDING	BLD 474
GATEHOUSE - MAIN SITE ENTRANCE/EXIT	BLD 475
VEHICLE FUEL STATION	FAC 480
EXHAUST SHAFT HOIST EQUIPMENT WAREHOUSE	BLD 482
SULLAIR COMPRESSOR BUILDING	BLD 485
DBL. WIDE TRAILER - VACANT - TO BE EXCESSED	TRL 906
SINGLE WIDE TRAILER - OFFICE	TRL 907
SINGLE WIDE TRAILER - OFFICE	TRL 908
SINGLE WIDE TRAILER - CABLE FABRICATION	TRL 908A
SINGLE WIDE TRAILER - LAB AND CABLE FABRICATION	TRL 908B
DBL. WIDE TRAILER - OFFICE	TRL 909
DBL. WIDE TRAILER - OFFICE AND LAB	TRL 910
SINGLE WIDE TRAILER - VACANT - TO BE EXCESSED	TRL 911A
SINGLE WIDE TRAILER - OFFICE	TRL 911B
SINGLE WIDE TRAILER - OFFICE	TRL 911C
SINGLE WIDE TRAILER - AIS STAGING	TRL 911E1
SINGLE WIDE TRAILER - VACANT - TO BE EXCESSED	TRL 911E2
DBL. WIDE TRAILER - COMPUTER CENTER	TRL 911F
SINGLE WIDE TRAILER - CABLE FABRICATION	TRL 911G
DBL. WIDE TRAILER - OFFICE AND CLASSROOMS	TRL 912
TRAILER COMPLEX (7) - OFFICE	TRL 914
SINGLE WIDE TRAILER - OFFICE	TRL 914A
SINGLE WIDE TRAILER - OFFICE	TRL 915
TRAILER COMPLEX (4) - OFFICE	TRL 916
SINGLE WIDE TRAILER - AIS DATA AQUISITION	TRL 917
SINGLE WIDE TRAILER - CHANGE ROOM	TRL 931B
DBL. WIDE TRAILER - OFFICE	TRL 971
DBL. WIDE TRAILER - OFFICE	TRL 982
SINGLE WIDE TRAILER - OFFICE	TRL 984
DBL. WIDE TRAILER - OFFICE	TRL 985
DBL. WIDE TRAILER - OFFICE	TRL 986
DBL. WIDE TRAILER - OFFICE	TRL 988
SINGLE WIDE TRAILER - OFFICE	TRL 991
SINGLE WIDE TRAILER - LAB	TRL 992
SINGLE WIDE TRAILER - LAB	TRL 993
MOBILE STORAGE BUILDINGS	24Z002 THRU 24Z017

FAE259.6-1

FIGURE 2.3 (CONCLUDED)
SURFACE FACILITIES AT THE WIPP

2.2.2 Underground Facilities

The constructed underground facilities include four shafts, the waste disposal area, the experimental area, an equipment and maintenance facility, and connecting tunnels (FEIS Subsections 8.2 and 8.4). The four shafts (Figure 2.4) from the surface to the underground area are:

- Air intake shaft
- Salt handling shaft
- Waste handling shaft
- Exhaust shaft.

The underground facility, as described in Subsection 8.2.2.2 of the FEIS, was mined in the Salado Formation, 2,150 ft beneath the surface. The underground facility was mined in the same design as described in the FEIS, but was reconfigured from the north to the south of the shaft pillar area because of its proximity to pressurized brine reservoirs in the Salado Formation. The "room and pillar" arrangement includes two separate mined areas:

- CH and RH TRU waste disposal area (100 acres designed to hold 6.2 million ft^3 of CH TRU and 250,000 ft^3 of RH TRU waste). To date, about 15 acres have been mined.

- Experimental area (12 acres) used for repository safety and mine performance studies.

Not all waste disposal rooms have been mined at present because of the natural phenomenon of salt creep, which causes eventual room closure. Additional waste disposal rooms would be mined in advance of permanent waste emplacement.

2.3 WASTE TYPES AND FORMS

Post-1970 defense-generated TRU waste results primarily from plutonium reprocessing and fabrication as well as from research and development activities at various DOE defense program facilities. TRU waste is material contaminated with alpha-emitting radionuclides having atomic numbers greater than 92, half-lives greater than 20 years, and concentrations greater than 100 nanocuries per gram (nCi/g) of waste. Prior to 1982, TRU waste was defined as having greater than 10 nCi/g of alpha-emitting radionuclides. Waste with TRU concentrations between 10 and 100 nCi/g has been reclassified as low-level waste, and would be disposed of in low-level waste disposal facilities. TRU waste exists in a variety of physical forms, ranging from unprocessed laboratory trash (e.g., tools, paper, glassware, gloves) to solidified wastewater treatment sludges (Appendix B).

TRU waste is classified according to the radiation dose rate at the package surface. The greatest percentage of defense TRU waste by volume (97 percent) is CH TRU waste, which primarily emits alpha radiation. These radionuclides, while potentially dangerous if inhaled or ingested, do not represent an external radiation hazard.

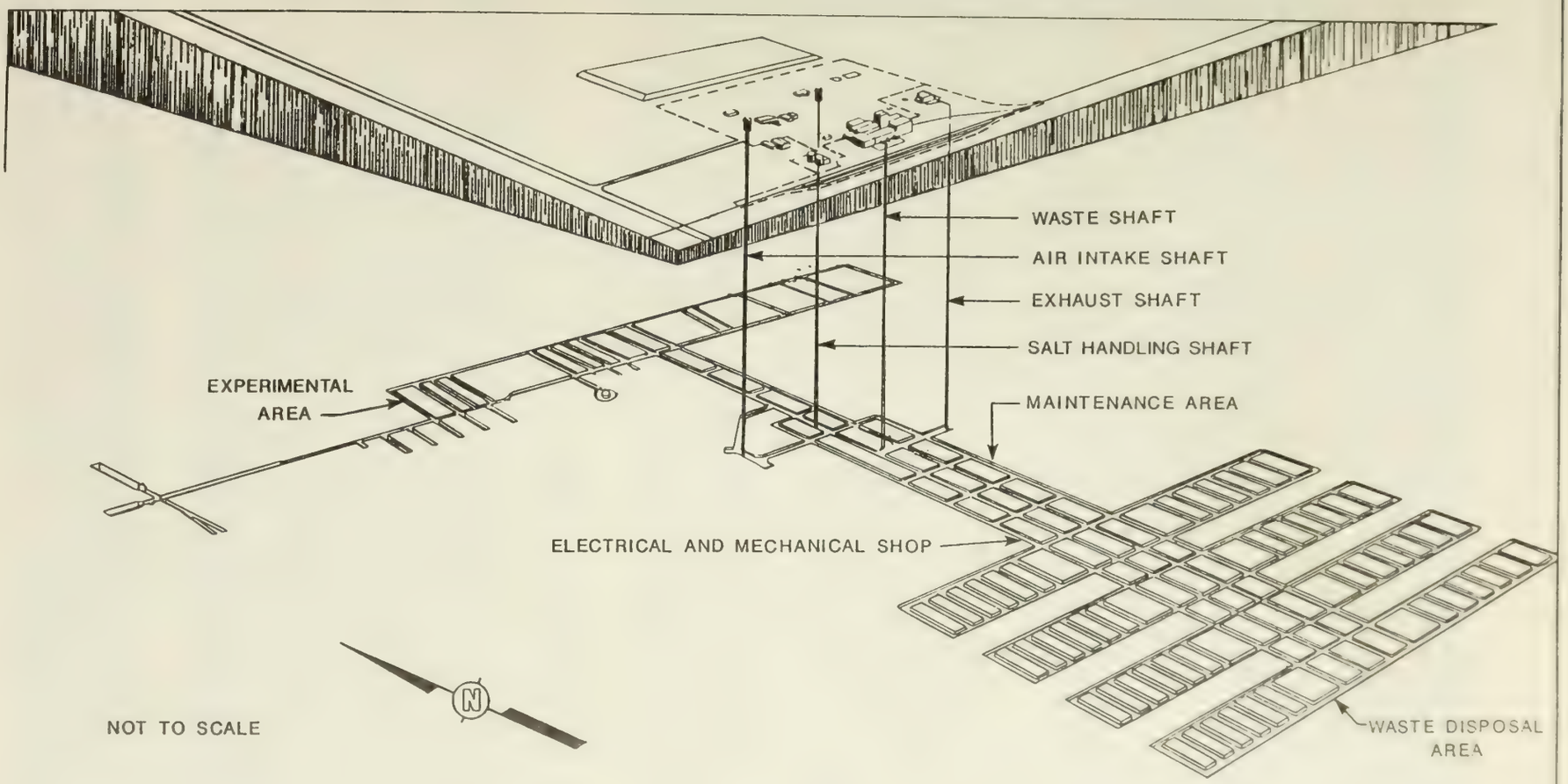


FIGURE 2.4
SCHEMATIC OF THE WIPP REPOSITORY

LIBRARY OF THE UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

CH TRU waste has radiation dose rates at the package surface below 200 millirem per hour (mrem/hour) and can be safely contact-handled (i.e., personnel may directly handle these waste packages without excessive radiation exposure). CH TRU waste is packaged in sealed steel drums and boxes that are vented with carbon composite filters to prevent the buildup of gases.

Approximately 5.3 percent by curies and 1.6 percent by volume of post-1970 defense TRU waste is RH waste, which contains isotopes that emit beta and gamma radiation as well as alpha radiation. This waste has a package surface radiation dose rate exceeding 200 mrem/hour and must be remotely handled. (Appendix A describes waste-package surface dose rate restrictions.) RH TRU waste requires heavy shielding for safe handling and storage, so it is handled and transported in lead-shielded casks. Subsection 3.1.1 provides a comparison of CH and RH TRU waste volumes considered in the FEIS and in this final SEIS and a description of the changes in the waste types (e.g., high-curie and high-neutron) that may be disposed of at the WIPP.

Potentially hazardous chemical constituents are often commingled with TRU waste from defense-related operations resulting in a classification of waste referred to as "mixed waste." The hazardous chemical components of defense TRU mixed waste were not addressed in the FEIS. TRU waste containing hazardous chemical constituents has similar physical and radiological characteristics to TRU waste that does not contain these constituents. A major chemical constituent in TRU waste is lead, which is present predominantly in the form of glove box parts and lead-lined gloves and aprons. Other metals (e.g., cadmium, chromium, uranium, and barium) are also present in some of the waste (e.g., sludges), but in much smaller quantities. Organic solvents (e.g., methylene chloride, toluene) are present in some waste types. These solvents exist primarily in residual quantities from the cleaning of equipment, plastics, and glassware. Subsection 3.1.1.2 presents the characteristics of the hazardous chemical constituents of defense TRU mixed waste.

2.3.1 Waste Acceptance Criteria (WAC)

The DOE has established WAC for waste coming to the WIPP (DOE, 1989a) (See Appendix A). These criteria establish conditions governing the physical, radiological, and chemical composition of the waste to be emplaced in the WIPP, as well as specifications for waste packaging to provide for the health and safety of workers and the public. The WAC also considered the U.S. Department of Transportation (DOT), the U.S. Environmental Protection Agency (EPA), and the Nuclear Regulatory Commission (NRC) regulations existing at the time and adopted several of the limits. The DOT and the EPA (40 CFR Part 263) regulate the safe transport of radioactive and hazardous materials. (The NRC has issued a certificate of compliance for the TRUPACT-II shipping container (Subsection 10.2.6 and Appendix L). An RH waste shipping cask will also be certified by the NRC.) When criteria of the various agencies overlap, the WAC conforms to those that are most restrictive.

The WAC were established based upon the radiological hazards of TRU waste and those from associated nonradiological chemical constituents. The chemical criteria of the WAC are primarily oriented toward preventing immediate safety hazards such as fire and explosion during transportation and handling. The labeling and data package

criteria of the WAC provide for the identification of hazardous chemical characteristics of TRU mixed waste in compliance with the Resource Conservation and Recovery Act (RCRA).

A detailed discussion of the WAC and the bases upon which these criteria were established are contained in a recent report (DOE, 1989a). A summary of the current WAC is given in Appendix A. The WAC have been modified since 1980 and are likely to undergo revisions in the future. Revisions would be dependent, in part, upon results of the Test Phase; such revisions would require appropriate National Environmental Policy Act of 1969 (NEPA) review of the system-wide impacts. The changes to the WAC since 1980 (FEIS Subsection 5.1) are summarized below:

- Gas Generation. Eliminated the volume and density limits by requiring pressure relief on waste packages and provided for data relevant to calculation of gas generation. Added prohibition of gases that could dramatically reduce the effectiveness of the packaging during transportation.

- Immobilization. Replaced requirement for immobilization of all powders with requirement for immobilization if more than 1 percent by weight of the powder is composed of particulates less than 10 microns (μm) in diameter or if more than 15 percent by weight is less than 200 μm in diameter. The requirement for no free liquids was revised to allow minor liquid residues remaining in drained containers.

- Toxics and Corrosives. Revised to include "radioactive mixed waste" and added a requirement to report the quantities of these constituents for accumulation records.

- Sludges. Requirements were deleted; sludges are now covered under immobilization requirements.

- Waste Container Design Life. Twenty years from the date of certification.

- Waste Package Weight. Reduced from 25,000 lb to 21,000 lb.

- Criticality. RH TRU waste increased from less than 5 grams per cubic foot (g/ft^3) of fissionable radionuclide content to 600 g total per canister.

- Thermal Power. RH TRU waste reduced from 500 watts (W) to 300 W to limit maximum underground heat load.

- Specific Activity. Added requirement that the concentration of TRU radionuclides must be greater than 100 nCi/g to segregate low-level waste from TRU waste.

- Activity Concentration. Added requirement that the concentration of activity is limited to 23 curies per liter (Ci/l) averaged over the volume.

In addition, a concept of "plutonium-239 equivalent activity" (PE-Ci) was introduced in the WAC changes (Appendix F). The PE-Ci concept was intended to eliminate the need for site-specific radiological analyses and instead depends on knowledge of the specific radionuclide composition of a TRU waste stream. A unique radionuclide composition is associated with virtually every TRU waste generator and storage facility. By "normalizing" radionuclides to a common radiotoxic hazard index, radiological analyses can be conducted for the WIPP that are independent of these variations. Plutonium-239, as a common component of essentially all defense TRU waste, was selected as the radionuclide to which the radiotoxic hazard of other TRU radionuclides could be indexed.

The FEIS did not use the 1,000 PE-Ci limit established subsequently in the WAC for calculating occupational and public radiation doses during routine and accident conditions. The FEIS used representative waste from the Rocky Flats Plant for radiological analyses. Subsequent to the FEIS, radiological performance analyses for normal operations and operational accident scenarios using the 1,000 PE-Ci limit were performed to support Amendment 9 of the WIPP Safety Analysis Report (FSAR) (DOE, 1989b). These analyses demonstrated that the doses remain well within prescribed regulatory limits and/or guidelines and that, although they are somewhat higher, the projected doses do not change the radiological consequences significantly.

To demonstrate compliance with the WAC, the DOE requires that generators handling defense TRU waste develop and implement a program that establishes procedures for waste certification and quality assurance. Each site-specific plan identifies and describes the administrative controls and procedures required to characterize TRU waste, segregate and process waste forms, and package waste in accordance with the WAC. Stored TRU waste will undergo nondestructive, nonintrusive analyses, such as container integrity examinations, weighing, radiological examinations, fissile inventory examination, and radiographic surveys of containers prior to certification. A waste certification officer at each generator facility inspects each container of waste and certifies in writing that the waste meets the specifications of the WAC. An independent DOE Certification Committee conducts either an annual or biennial audit of each facility's certification program, depending on the quantities of TRU waste generated at the facility, and approves the certification program for waste to be shipped to the WIPP.

2.3.2 Processing of TRU Waste

Since the FEIS was issued, the development of the WAC (Subsection 2.3.1) has made certain waste processing and packaging practices unacceptable. The DOT, NRC, and EPA transportation requirements have imposed additional restrictions on waste forms. As a result, some generator facility practices have changed and activities at facilities for retrievably-stored waste have been modified.

Gas generation considerations for transportation have resulted in the introduction of vented waste packages at generator and storage facilities that are expected to ship TRU waste to the WIPP. The vents in such packages incorporate HEPA (high-efficiency particulate air) grade carbon composite filters. Prior to shipment, all packages must have these vents.

The WAC requirement for immobilization of ashes and powders has impacted the handling of these materials. Floor sweepings, machine cuttings, and similar materials are now being immobilized in cement or other media. Proposed waste processing systems at generator facilities (principally facilities for packaging waste) have been designed to reflect the requirements of the WAC for such ash and powder substances. Representative processing systems are described in Subsection 6.4.1.

The WAC limits free liquid in waste packages to small residual amounts. This criterion is being met by a combination of generator facility actions. In some cases, improved process control and the addition of absorbents have ensured that packaged sludges meet the free liquid criterion. There is also a trend for generators to modify their liquid and sludge processing practices to provide a monolithic solid waste form. These practices are described in Subsection 6.4.1.

Approximately 60 percent of the total TRU waste inventory is estimated to be classified as mixed waste with radioactive and hazardous chemical components. Current generator facility practices minimize the number of mixed-waste packages by a combination of improved waste segregation and reduction of the use of hazardous chemical materials. The WAC's elimination of explosives and compressed gases is also being addressed by improved controls during waste segregation and packaging.

Some facilities use reactive, potentially pyrophoric metals in their operations. Waste containing these metals is processed to reduce reactivity either by chemical reaction or by immobilization.

2.4 WASTE RECEIPT AND EMPLACEMENT

Procedures for receiving and handling waste aboveground at the WIPP's waste handling building are described in Subsection 8.3.1 of the FEIS and remain unchanged. Waste would enter the building through air locks that control the movement of air. Three such air locks provide for entry into the CH TRU waste side of the building. The air locks are designed to help maintain the interior of the building at a pressure lower than atmospheric. The doors at each end of the air lock are interlocked to prevent both doors from being opened simultaneously. The air locks help ensure that airflow is into the building, thereby precluding the inadvertent release of potential radioactive contamination from the building.

The ventilation system is designated as a dynamic confinement barrier in the building's multibarrier confinement system. In the waste handling areas the ventilation system maintains a static pressure differential (negative pressure) between the primary confinement barriers (drums, boxes) and the environment. Air locks between different zones of potential contamination are designed to separate areas in which pressure differentials are maintained to ensure airflow from areas of lower to higher contamination potential. The building with its HEPA filtration system acts as a secondary confinement barrier. This system is part of the dynamic ventilation system and provides the last barrier to prevent contaminated airborne particulates from leaving the plant. The design includes redundant features and is such that individual filters can be replaced without any air bypassing the HEPA system (DOE, 1989b).

2.4.1 Waste Receipt

During the Test Phase, CH TRU waste would be received and emplaced at the WIPP in such a way as to maintain retrievability. CH TRU waste would be received in two forms of Type A packagings, 55-gal drums or standard waste boxes (SWBs) (boxes 37 inches high by 72 inches in diameter), which are in turn contained within Type B shipping packagings (TRUPACT-II). Each TRUPACT-II would contain fourteen 55-gal drums or two SWBs (Subsection 3.1.1.3). The packages would be checked for surface contamination, and if uncontaminated, would be unloaded in the receiving and inspection area.

Contaminated packages would be moved to the overpack and repair room, where they would be examined and overpacked or repaired if necessary. When inspection shows that the waste packages are uncontaminated, and if the accompanying documentation shows that they meet the WIPP WAC (DOE, 1989a) and regulatory requirements (40 CFR Part 264, Subpart E--Manifest System, Recordkeeping, and Reporting), they would be moved to the CH TRU waste inventory and preparation area. At that location, packages would be stacked on pallets for uniform handling and would be transferred underground through the waste shaft. The TRUPACT-IIs, emptied of the waste packages, would be decontaminated, if necessary, for reuse and loaded onto transport vehicles leaving the plant.

During the Disposal Phase, RH TRU waste would be received in NRC-approved (Type B) shielded shipping casks. Each cask, containing one canister of waste, would be inspected and unloaded from the transport vehicle in the cask unloading and receiving area of the waste handling building. It would then be moved to the cask preparation and decontamination area. At this location, any contamination would be removed and special handling equipment would be attached to the cask.

The RH casks would be transferred to the cask unloading room, where the canisters would be removed and placed in a shielded "hot cell." After identification and inspection, during which any contaminated canister would be decontaminated or overpacked, the canister would be placed in the transfer cell. The canister would be removed from the transfer cell and loaded into a specially designed facility cask and lowered underground via the waste shaft. The shipping cask would be surveyed and decontaminated, if necessary, and returned to the shipper for reuse.

2.4.2 Waste Emplacement

CH TRU waste would be transferred on pallets to the underground waste receiving station in a hoist cage designed to handle a payload of 45 tons. At this station, the waste pallets would be unloaded and transported to the waste disposal areas. A decontamination and radiation safety check station would be located near the waste shaft on the waste disposal level.

During the Test Phase, backfilling with crushed salt and/or other additives would only be undertaken to the extent necessary to satisfy the goals of the tests and in a manner that allows for waste retrieval (i.e., not allowing salt creep to crush the waste packages).

During the Disposal Phase, each room (33 ft wide, 13 ft high, 300 ft long) would be backfilled with crushed salt and/or other additives (e.g., bentonite, gas-absorbing materials) as the containers are emplaced.

The RH TRU waste facility cask would be lowered in the hoist cage to the underground waste receiving station and transported by forklift to a waste disposal area. The RH TRU waste canisters would be horizontally emplaced in holes in the walls of the disposal rooms or selected drifts.

2.5 WASTE RETRIEVAL AT THE WIPP

During the Test Phase, the waste emplaced in the WIPP must be readily and safely retrievable. Based upon the results of the Test Phase, the DOE would decide whether to retrieve the waste. A draft retrieval plan has been prepared (DOE, 1989c).

Many of the activities supporting retrieval of waste are similar to emplacement activities, although during the Test Phase the waste disposal room would begin to close, and consequently, the condition of the containers may be impacted.

The retrieval process in the bin-scale test room (see Appendix O) can be summarized as follows:

- Survey drifts and the room for contamination and take worker protective action as needed
- Evaluate condition of drifts, and the room, and conduct operations as required to prepare for retrieval
- Install contamination barrier with worker airlock, and equipment and waste transfer room
- Monitor for radiation and take protective action as needed
- Install HEPA vent system filtration
- Verify air circulation system is operating correctly
- Survey bins and place contaminated bins in plastic bags
- Overpack contaminated bins in SWBs
- Transport waste to the surface and move it to overpack and repair room
- Remove from overpack and stabilize brine as needed by bin inversion, evaporation, and removal, or injection of stabilizing materials
- Overpack bins into SWB

- Load into TRUPACT-II
- Dismantle bin racks and, if contaminated, treat as radioactive waste
- Ship to facility of origin (assumed for purposes of this SEIS)

The retrieval process in the alcove-scale test (see Appendix O) can be summarized as follows:

- Evaluate condition of drifts, entryways, and alcoves, conduct operations as required to prepare for retrieval
- Install contamination barrier with worker airlock and equipment and waste transfer room
- Install vent system HEPA filtration
- Monitor for radiation and take protective action if needed (protective gear and disposal of waste if contaminated)
- Isolate and reconfigure gas recirculation system for retrieval
- Depressurize alcove and establish breathable atmosphere
- Deflate seals and survey for contamination and take protective action, if needed
- Conduct operations as appropriate for decontamination
- Remove backfill and handle as radioactive waste if appropriate
- Survey drums; bag and overpack contaminated drums into SWB
- Transport waste to the surface and move it to overpack and repair room
- Remove from overpack and stabilize brine as needed
- Overpack drums into SWB
- Load into TRUPACT-II
- Ship to facility of origin (assumed for purposes of this SEIS).

The retrieval process for the operations demonstration is similar to that for the alcove-scale test.

A decision as to whether to retrieve the waste that would be emplaced during the Test Phase would be made after consideration of an updated SEIS, a determination of compliance with Subpart B of 40 CFR Part 191, the EPA disposal standards for TRU

waste, the RCRA land disposal restrictions discussed, respectively, in Subsections 10.2.4 and 10.2.1, and any other applicable regulations. In the Disposal Phase, the WIPP would be designed and operated to comply with the assurance requirement of 191.14(f) of 40 CFR Part 191 so that ". . . removal of most of the waste will not be precluded for a reasonable period of time after disposal."

If, during the Test Phase, there were a significant indication of noncompliance with Subpart B of 40 CFR Part 191 or the RCRA, a number of program modifications to achieve compliance such as waste treatment, and engineering barrier or design modifications, would be considered. If engineering modifications or waste treatment were proposed for the WIPP, the waste would either be brought to the surface or moved to other subsurface storage areas within the WIPP and temporarily stored in an environmentally safe manner. Such storage would continue only until such time as engineering and design modifications or treatment could be completed and permanent disposal of the waste could be accomplished. If only the addition of a modified backfill were required, it would be installed with the waste in place or by moving the waste from the Test Phase locations to new locations, and emplacing it with the appropriate backfill at new locations.

If it were determined, however, after considering various options that the WIPP could not comply with regulatory requirements, the waste would be retrieved as described above and placed in storage. It is assumed for purposes of analysis in this SEIS that the retrieved waste would be transported back to the DOE facility from which it was originally received.

Appropriate NEPA documentation would be prepared prior to any of the above decisions.

2.6 PLANS FOR DECOMMISSIONING

Assuming the WIPP moves into the Disposal Phase, when the disposal operations cease, the site would be decommissioned in a way that would allow for the safe, permanent disposition of surface and underground facilities consistent with the then-applicable regulations. Plans for decommissioning remain the same as described in FEIS Subsection 8.11 and include the following options:

- Mothballing. The plant would be placed in protective storage for a few decades, which would allow for later repository operation or experiments. The facilities would be left intact and any radioactive areas would be isolated from the public by barriers. Complete radiation monitoring, environmental surveillance, and security procedures would be established to protect the environment and public health and safety.

- Entombment. Usable equipment would be decontaminated and removed. Equipment that might not be decontaminated would remain underground. Entombment would require filling the mine with salt and plugging the shafts and boreholes. The surface facilities would then be available for future use.

- Dismantling. The plant would be entombed as above. Surface facilities would be decontaminated, then demolished or dismantled, and debris removed. The site landscape would be returned to as near its original condition as possible.

- Converting. The plant would be put to another use when WIPP operations are complete. This option would take advantage of roads, rail spurs, and utilities currently at the site.

Institutional controls as required by 40 CFR Part 191 would be imposed to minimize human intrusion, such as deep drilling, mining, or any activity that might allow water to penetrate the disposal area. It is expected that the shafts would be permanently marked with durable warning monuments. Documents concerning the WIPP would be maintained in public document repositories.

The WIPP is subject to RCRA regulation 40 CFR Part 264, Subpart X, which pertains to miscellaneous units. As a RCRA-regulated unit, the WIPP must also comply with Subpart G of 40 CFR Part 264, which covers closure (the period when waste is no longer accepted and the site is decontaminated and prepared for decommissioning) and the postclosure period (the period following complete closure when the area is monitored and maintained to ensure integrity of the disposal system). Consistent with these regulations, closure and post-closure plans would be prepared and maintained at the WIPP site. The closure plan would describe partial closure of each unit (room), final closure of the facility, and waste retrievability features. If waste is retrieved after the Test Phase, the closure plan would be amended in accordance with 40 CFR 264.112.

2.7 SITE EMERGENCY PLANNING AND SECURITY

The FEIS (Subsection 8.12) describes precautions, emergency actions, and procedures to be taken in response to radiation-related and other emergencies at the WIPP. Procedures and actions include:

- Advance training and coordination with local law enforcement, fire, and medical personnel

- A central monitor/control system to coordinate and record emergency alarms and serve as a control center during emergencies

- Location and maintenance of firefighting vehicles aboveground and belowground

- Medical capability for treating contaminated or injured persons before their transfer to a hospital

- Written procedures specifying response to the unplanned release of radioactivity, fire, cave-ins, explosions, radiation, and other emergencies

- An emergency response force composed of personnel (firefighting, medical, security, mine rescue, and radiation control) who would take immediate action to assess, control, contain, and recover from the emergency

- Special immediate action training and formal qualification for the emergency response force

- Set up and staffing of the Emergency Operations Center (EOC) with senior management personnel activated to provide centralized response to emergencies

- Quarterly emergency response drills utilizing specially developed contingency scenarios to test the capabilities of emergency response personnel.

These actions and procedures have been accomplished and are currently in place at the WIPP site and in the communities of Carlsbad and Hobbs, New Mexico. Additionally, exercises have been conducted to test capabilities, primarily in the areas of security, underground fire, surface fire, medical emergencies, underground evacuation, mine rescue, and radioactive spills and contamination. The EOC has been used during most of these exercises.

At the conclusion of each exercise, action assignments are established to improve response capability. Corrective action, the person responsible, and the date the action is due are noted in a "drill actions item" log. Action items are reviewed in monthly planning meetings and removed from the log only when the improvement has been made.

Memoranda of Understanding have been executed with medical, fire, and law enforcement personnel in Carlsbad and Hobbs, New Mexico. In 1986, the DOE and Eddy County, New Mexico, signed a mutual aid agreement in which the Otis Volunteer Fire Department agreed to respond to WIPP site fires. In turn, the WIPP committed its forces to respond to fire, medical, and rescue situations within a 60-square-mi area of Eddy County. As a result, the WIPP Emergency Action Team has responded to traffic accidents and suppressed one major fire. The policy is to respond to anyone in need of help where life or health is involved, as long as it does not jeopardize the safety or security of the WIPP site.

The site security plan for the WIPP complies with DOE Order 5632.2A (DOE, 1988a) regarding guards, fencing, building construction, and access control. It also meets RCRA security requirements, including "a 24-hour surveillance system which continuously controls entry onto the active portion of the facility, a fence which completely surrounds the active portion of the facility, a means to control entry, at all times, through the gates or other entrances to the active portion of the facility, and signs with the legend 'Danger-Unauthorized Personnel Keep Out' . . . written in English and in any other language predominant in the area surrounding the facility," in this case, Spanish (40 CFR 265.14).

Additional security provisions for the site have been implemented, including security clearances for selected site employees, visit and assignment authorization for foreign

nationals, visitor documentation, information protection, and key and lock controls (DOE, 1989b). Since the FEIS was completed, upgrades have been proposed to expand the fenced security area from 250 to 1,454 acres, prohibit grazing inside the security area, and arm the security staff.

2.8 TRANSPORTATION EMERGENCY PLANNING

The transportation emergency preparedness program described in Subsection 6.11 of the FEIS has been implemented (SEIS Appendix C). Achievements of this ongoing program to date include:

- Interfaces with local, State, and Federal government agencies and Indian Tribal governments have been established
- The States Training and Education Program (STEP) for first responders is on schedule
- The public awareness tour has been completed in five States and has received much positive media coverage
- The transport tracking system hardware and software have been tested and proven; this system has been made available to State and Federal government agencies and Indian tribal governments. The system would provide accurate tracking of shipments to the WIPP.

This subsection describes the progress that has been made in these programs since publication of the FEIS and includes discussion of the overall emergency preparedness plan, implementation of the plan, State emergency plans, and response training.

As discussed in Subsection 2.7 above, an overall emergency preparedness plan for the WIPP has been prepared (DOE, 1988a). The plan describes measures to be taken in the event of an on-site or off-site emergency, including transportation emergencies. The plan generally requires that transportation accident response be handled by the waste shipper with assistance as necessary by the DOE and local/State authorities.

The DOE has undertaken an extensive public information program for persons and authorities in the 23 affected States and Indian Tribal governments that are along proposed TRU waste transportation routes. These individuals and authorities have been informed of the potential hazards of the waste. As part of this notification, public awareness tours have been (and are being) conducted (Appendix H). This tour includes a display that explains the WIPP, the types of waste, the transportation routes, and includes a model of the TRUPACT-II container. The public awareness tour has been completed in 29 municipalities along the route from Idaho Falls, Idaho, to Carlsbad, New Mexico. Additionally, the tour will be offered to States along the remaining routes before waste would be transported along those routes. The DOE also displays the exhibit to various interstate agencies (e.g., Western Interstate Energy Board, Southern States Energy Board, and the Western Governors' Association). Finally, the exhibit has been displayed at various conferences (e.g., Waste Management 1988 and

1989, Texas Emergency Managers Conference, American Chemical Society, and others), as appropriate.

State emergency plans from the 23 affected States have been reviewed by the DOE to ensure that 1) a State representative with radiological training would be a responder should an accident occur, and 2) the responsible State contact would activate the DOE Radiological Assistance Program (RAP). The RAP is a nationwide program that provides assistance by DOE personnel on the scene of any accident involving radioactive materials.

The DOE has developed a program that offers to train State, local, and Indian Tribal police and emergency personnel in the proper procedures to be followed in the event of a transportation accident. The emergency procedures and responses described in Subsection 6.11 of the FEIS summarize the procedures that are taught in the training sessions. As of September 1989, more than 3,600 firemen, policemen, and emergency medical personnel in the States of Idaho, Utah, Wyoming, Colorado, and New Mexico have been trained. It is estimated that by the end of November 1989, approximately 300 hospital based emergency medical personnel will have been trained in the States of Idaho, Utah, Wyoming, Colorado, and New Mexico. About 1,600 state personnel along the route from Savannah River to the WIPP (South Carolina, Alabama, Georgia, Mississippi, Louisiana, and Texas) have been trained. Personnel from the remaining 12 states along the transportation routes are scheduled for training prior to the transport of waste through those States. Six different courses are offered. The courses include an 8-hour "First Responder" course for fire, law enforcement, and medical first responders plus a 4-hour refresher course for those who have previously attended the first responders course. In addition, a 16-hour "Command and Control" course, a 4-hour mitigation course for State radiological health personnel, a 12-hour "Train the Trainer" course for State certified trainers, and an 8-hour medical emergency management course for hospital staff are offered.

The DOE has developed a transportation satellite tracking and communication system. This system has been designed, in part, to enhance emergency response capabilities. Emergency response would be faster because the location of each waste shipment is constantly tracked. One feature of the system is an emergency checklist that explains precautions to be taken in the case of an accident that results in the release of a hazardous substance. This information is specific to the material being transported.

The emergency preparedness program for the WIPP also includes the training of local hospital staff. A Memorandum of Understanding has been agreed to by the DOE and the Guadalupe Medical Center in Carlsbad, New Mexico, and the Lea Regional Hospital in Hobbs, New Mexico. The purpose is to provide for 1) emergency equipment to be loaned to the two hospitals and 2) training of hospital staff to handle accident victims who have been exposed to radioactivity. Emergency equipment, such as decontamination table tops and decontamination kits, have been supplied to the two hospitals. Medical training of local hospital staff will take place. Additional details are included in Appendix C.

2.9 ENVIRONMENTAL MONITORING PROGRAMS

As reported in the 1980 FEIS (Appendix H), background radiation levels and selected air pollutants have been measured at the WIPP site since 1976.

The DOE continues to conduct or fund comprehensive environmental monitoring programs. Since the 1980 FEIS, these programs have been designed to characterize environmental baseline conditions at the WIPP and include:

- Radiological Baseline Program
- Ecological Monitoring Program
- Cooperative Raptor Research Program
- Environmental Evaluation Group Monitoring Program.

The scope of each of these studies is described in this subsection. The results of these studies are included in Subsections 4.1 and 5.1.

2.9.1 Radiological Baseline Program (RBP)

The Radiological Baseline Program (RBP) was initiated in 1984 to establish a statistically sound base of preoperational radiological data against which operational radiation measurements can be assessed. The RBP consists of five subprograms:

1) Atmospheric Radiation Baseline. This includes eight low-volume air sampling stations where airborne particulates are continuously collected and analyzed for radioactivity and seven high-volume air sampling stations where airborne particulates are collected intermittently.

2) Ambient Radiation Baseline. This includes 44 stations with thermoluminescent dosimeters and one station with a high-pressure ionization chamber to monitor penetrating radiation. An aerial measurement survey was conducted in April 1988 to map gamma radiation over a 156-square mile area around the WIPP site.

3) Terrestrial Radiation Baseline. This includes 37 stations where soil samples have been collected.

4) Hydrologic Radiation Baseline. This includes 10 stations where surface water is collected (bottom sediments are also collected at four of these stations) and 23 project wells and 10 private wells where groundwater is collected.

5) Biotic Baseline. This includes the sampling of native vegetation, and fauna, including local cattle, small game animals, game fish, and game birds.

Radiochemical analysis for the RBP includes not only radionuclides present in the waste but also radionuclides present in fallout and occurring naturally. All major environmental media potentially affected by WIPP activities are sampled. Results of the RBP are presented and discussed in the annual WIPP Environmental Monitoring

Reports (Reith et al., 1985a; Banz et al., 1987; and Flynn, 1988). To date, RBP results in the region of the WIPP are within the ranges of environmental radioactivity expected by the National Council on Radiation Protection and Measurements (NCRPM, 1975, 1977) and Federal agencies (DOE, 1980).

2.9.2 Ecological Monitoring Program (EMP)

The (EMP) Ecological Monitoring Program is the functional successor to the WIPP Biology Program that was initiated in 1975 to perform baseline nonradiological ecological studies prior to the start of WIPP construction. The WIPP Biology Program results are reported in Subsection 7.1 of the FEIS. The EMP focuses on the vegetation and animal communities immediately surrounding the site and on the ecological parameters most likely to reflect the impact of construction and operational activities. The EMP consists of six subprograms:

- Meteorology. Temperature, relative humidity, barometric pressure, precipitation, and wind speed and direction are monitored continuously at the site.

- Air Quality. Atmospheric gases (hydrogen sulfide, sulfur dioxide, carbon monoxide, ozone, and nitrogen oxides) are continuously monitored at the site.

- Water Quality. Surface water, groundwater, and sediments are sampled periodically to determine the impact of WIPP construction.

- Aerial Photography. Aerial photographs are taken twice a year to document changes in the extent of land use and habitat disturbance.

- Vertebrate Census. Breeding bird and small mammal populations are surveyed annually to monitor for WIPP-related changes in population densities.

- Salt Impact Studies. This subprogram has four components:

  1) Surface Photography. Fixed-location surface photographs are taken semiannually in each permanent monitoring plot to document alteration of habitat structure.

  2) Soil Chemistry. Soil samples are collected at three depths (0 to 0.8 inch, 11.8 to 17.7 inches, and 23.6 to 29.5 inches) and analyzed for direct evidence of salt-related chemical changes in the soil.

  3) Soil Microbiota. Microbial activity levels and decomposition rates are monitored in recognition of the role these organisms play in maintaining energy flow through the ecosystem and their sensitivity to chemical changes in the soil.

4) Vegetation Survey. Foliar cover, species composition, and the density of annual species are monitored for indications of salt-related impacts on native vegetation in the ecosystem.

In general, the EMP has shown few adverse environmental impacts from the construction of the WIPP. Results of the EMP have been published in the Ecological Monitoring Program Reports (Reith et al., 1985b; Fischer et al., 1985; Fischer, 1987, 1988) and the Annual Site Environmental Report (Flynn et al., 1989).

2.9.3 Cooperative Raptor Research and Management Program

In 1985, the Los Medanos Cooperative Raptor Research and Management Program was initiated under the cosponsorship of the DOE, the BLM, and the Living Desert State Park. One goal of the study, conducted by researchers from the University of New Mexico, is to evaluate the impacts of WIPP activities on the breeding success of raptors (e.g., hawks and owls), some species of which are found in unusual abundance in the vicinity. Experiments are also being conducted to determine how these impacts may be mitigated.

Study results from 1986 (Bednarz, 1987) indicate that adverse impacts on nesting success resulting from human intrusion during critical times in the nesting cycle are measurably reduced by slight modification of fieldwork schedules to accommodate nesting activities. When nests have been found in locations potentially threatened by a nearby work area (such as a well pad), the Regulatory and Environmental Programs Section (REPS) at the WIPP has been notified and the scheduled use of the work area examined. Whenever possible, work schedules have been, and will be, modified to minimize impacts on the nests. Tests of artificial nest platforms to redirect nesting activity away from areas of disturbance and to replace lost nesting sites are also being conducted.

2.9.4 Operational Environmental Monitoring Program (OEMP)

In 1989, the DOE initiated the WIPP Operational Environmental Monitoring Program (OEMP), which is being phased in to replace the preoperational RBP and EMP. The OEMP plan (Mercer et al., 1989) was designed to continue the monitoring activities of the preoperational programs, combining both radiological and nonradiological surveillance into one program. It places greater emphasis on the WIPP site as a potential source of atmospheric and liquid effluents and reduces the emphasis on broad geographic monitoring. The OEMP incorporates the requirements for effluent monitoring at DOE facilities specified in the DOE Draft Order 5400.XY (DOE, 1988b).

Under the OEMP, effluent air from the repository and the waste handling building will be continuously monitored for radioactivity. Meteorological monitoring will be upgraded to provide real-time data to the Central Monitoring System for use in atmospheric dispersal models. Terrestrial radiation monitoring will give greater emphasis to locations of potential deposition of air and liquid effluents (e.g., site run-off). Also, 22 regional thermoluminescent dosimeter stations will be discontinued. The OEMP plan will be reviewed and updated annually throughout the operational period of the WIPP.

2.9.5 Environmental Evaluation Group Monitoring Program

The Supplemental Stipulated Agreement for Consultation and Cooperation specifies that the DOE provide the State of New Mexico with sufficient information to conduct an independent review of all WIPP activities. This review, presently performed for the State of New Mexico by the Environmental Evaluation Group (EEG), allows for an independent program of radiological surveillance conducted in parallel with the Radiological Baseline Program at the WIPP. The EEG receives water, soil, and biotic samples supplied by WIPP Environmental Programs during routine collections, and from air sampling instruments located side-by-side with the DOE instruments. Once the WIPP is operational, the EEG will also conduct radiological analyses of particulate samples from the effluent air exhaust system which serves the underground portion of the facility. The Annual Site Environmental Report (Flynn et al., 1989) lists the number of sampling locations and sampling frequency for the water, soil, and biotic split samples provided to EEG, and the OEMP (Mercer et al., 1989) lists the same information for the sampling schedule after receipt of waste.

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3.0 DESCRIPTION OF THE PROPOSED ACTION AND ALTERNATIVES

This section describes the Proposed Action, the alternative of No Action, and the alternative of conducting only those tests that can be performed without the emplacement of waste underground until there is a determination of compliance with 40 CFR 191 Subpart B and other applicable regulations.[1] The alternatives of either conducting no tests involving waste or conducting tests with simulated, nonradioactive waste were rejected as unreasonable because they would not provide sufficient data for reducing uncertainty in assessing compliance with applicable standards. The Proposed Action is to proceed with the WIPP as described in the 1980 FEIS (FEIS Alternative 2, the Authorized Alternative, in Subsection 3.6.3.1), while incorporating the proposed modifications listed in Subsection 1.3 and discussed below.

3.1 PROPOSED ACTION

The Proposed Action is to proceed with a phased approach to the development of the WIPP as authorized by Public Law 96-164 and as modified by proposed changes discussed in Subsection 3.1.1 below and elsewhere in this final SEIS. Full operation of the WIPP (the Disposal Phase) would be preceded by a Test Phase described in Subsection 3.1.1.4.

A phased decision-making process relative to construction and operation of the WIPP has been pursued since the transuranic (TRU) waste disposal program's inception. This phased development began with site selection and characterization; proceeded through site design and validation to construction; would continue, if appropriate, with the Test Phase; and would conclude, if appropriate, with the Disposal Phase.

The DOE's decision to proceed with the WIPP project at a location in southeastern New Mexico followed a NEPA review that culminated in the public distribution of the FEIS in 1980. A Record of Decision (DOE, 1981a) was signed, and Alternative 2 of the FEIS was selected in early 1981. That alternative called for the development of the authorized WIPP, consisting of surface and underground facilities designed to emplace approximately 6.2 million ft^3 of contact-handled (CH) TRU waste and 250,000 ft^3 of remote-handled (RH) TRU waste in a 100-acre mined repository. The construction of a 20-acre underground area for short-term experiments to analyze and respond to technical questions regarding the disposal of high-level waste was also part of the decision. In order to provide final site validation and to verify the analyses used in the design of the underground facility, the construction of the WIPP was to be preceded by construction of two deep shafts and underground geologic experimentation. These experiments were proposed to measure rock response and to conduct tests with

[1] Vertical lines in the margins denote changes to the draft SEIS made in response to comments.

nonradioactive materials. The Site and Preliminary-Design Validation Program (SPDV) and the construction of most WIPP facilities have been completed.

3.1.1 Changes to the Proposed Action and New Information or Circumstances

This subsection describes specific proposed changes not covered in the 1980 FEIS, and new circumstances and information that have developed since 1980. These changes have been factored into the impact analyses in this final SEIS.

- Clarifying that the WIPP may eventually include permanent emplacement of post-1970 TRU waste from the 10 DOE generator facilities listed in Table 3.1. According to the 1981 Record of Decision, the WIPP was to initially dispose of waste in retrievable storage at the Idaho National Engineering Laboratory. After this waste was emplaced at the WIPP, the WIPP would then be available to dispose of TRU waste from ". . . other defense waste generating facilities, . . ." which were not specified by name.

  The 1980 FEIS focused on the total inventory of 6.2 million cubic feet of CH TRU waste and 250,000 cubic feet of RH TRU waste expected to be received at the WIPP over its 25-year operating life. In 1980 this amount included all of the CH and RH waste in retrievable storage at the Idaho National Engineering Laboratory, two-thirds of the estimated waste to be generated at all DOE facilities between 1980 and 1990, and all TRU waste to be generated at all facilities between 1990 and 2003.

  The DOE still proposes that the phased development of the WIPP proceed for the permanent emplacement of 6.2 million cubic feet of CH and 250,000 cubic feet of RH waste. This SEIS clarifies that the waste may eventually come directly from the 10 DOE generator facilities listed in Table 3.1. By analyzing the impacts of transportation and emplacement of post-1970 waste from all 10 DOE generator facilities, this SEIS updates the FEIS analyses of the environmental impacts of transporting to and emplacing in the WIPP only post-1970 TRU waste from Idaho National Engineering Laboratory and Rocky Flats Plant.

  The SEIS also updates the FEIS on retrieval, processing, and packaging of waste for proposed shipment to the WIPP in compliance with the current WIPP Waste Acceptance Criteria. In this regard, the SEIS discusses site-specific NEPA documentation that has been prepared since 1980 on TRU waste retrieval and processing at the Hanford Reservation and the Savannah River Site. Additional appropriate NEPA documentation will be prepared to address the impacts of retrieval, processing, and treatment (if appropriate) of post-1970 TRU waste at the various generator/storage facilities. However, the impacts of retrieving, processing, and packaging the waste as analyzed in the FEIS for Idaho National Engineering Laboratory (and updated in this SEIS) and for other facilities as analyzed in this SEIS are believed to be representative of impacts that would occur at the other generator/storage facilities (Subsection 5.2.1, and Appendix P).

TABLE 3.1 Estimated volumes of CH TRU waste in retrievable storage or projected to be generated through the year 2013

Waste facility[b]	Estimated volume (ft^3)[a]		
	Retrievably stored waste[c]	Newly generated waste[d]	Total
Idaho National Engineering Laboratory	1,073,710	9,920	1,083,630
Rocky Flats Plant[e]	0	2,037,600	2,037,600
Hanford Reservation	293,250	537,800	831,050
Savannah River Site	91,465	615,700	707,165
Los Alamos National Laboratory	250,910	302,300	553,210
Oak Ridge National Laboratory	19,160	42,000	61,160
Nevada Test Site[f]	21,290	0	21,290
Argonne National Laboratory--East[e]	0	3,800	3,800
Lawrence Livermore National Laboratory[e]	0	259,400	259,400
Mound Laboratory[e]	0	40,100	40,100
TOTAL	1,749,785	3,848,620	5,598,405

[a] Estimated volumes correspond to the Integrated Data Base for 1987 (DOE, 1987b). The volumes of waste used for the environmental analyses in this SEIS are higher and are based on the design capacity of the WIPP.

[b] Unless otherwise indicated, these sites both generate TRU waste and are designated TRU waste storage facilities.

[c] Stored as of December 31, 1986. From Table 3.5 in the Integrated Data Base for 1987 (DOE, 1987b).

[d] Generated from 1987 through 2013. From Table 3.16 in the Integrated Data Base for 1987 (DOE, 1987b).

[e] Facility that generates but does not store CH TRU waste (except limited quantities pursuant to Resource Conservation and Recovery Act [RCRA] regulations).

[f] Facility that does not generate TRU waste, but is a designated TRU waste storage facility.

- Changes in the volume of the TRU waste inventory. In 1980, it was contemplated that approximately 6.2 million ft^3 of CH and 250,000 ft^3 of RH TRU waste would be available for disposal at the WIPP. The WIPP as designed would be able to accommodate this volume of TRU waste. Recent estimates indicate that approximately 5.6 million ft^3 of CH TRU and 95,000 ft^3 of RH TRU waste are in retrievable storage at 6 generator/storage facilities or would be newly generated at these facilities and by an additional 4 facilities through the year 2013, the projected operating life of the WIPP (Tables 3.1 and 3.2). This lesser volume is currently estimated because of an improvement in recordkeeping and inventory sampling, a change in the definition of TRU waste (Appendix B), changes to the WIPP Waste Acceptance Criteria (WAC) (Subsection 2.3 and Appendix A), and expected facility process modifications that would result in waste minimization and volume reduction (e.g., Rocky Flats Plant supercompacter).

  This SEIS, however, assesses the impacts of the WIPP using the volume limits of 6.2 million ft^3 of CH TRU waste and 250,000 ft^3 of RH TRU waste to set an upper limit on the potential impacts of filling the WIPP repository to its design capacity. The WIPP design capacity is sufficient to encompass TRU waste generated from new or planned defense-related facilities through the year 2013 (e.g., Special Isotope Separation Facility and the proposed Modular High Temperature Gas Cooled Reactor at the Idaho National Engineering Laboratory). Thus, the impacts associated with transporting, receiving, and permanently emplacing waste from all 10 facilities is conservatively "bounded" by the SEIS analysis.

- Changes in the composition of the TRU waste radioactive inventory to include high-curie and high-neutron waste, and to eliminate high-level waste experiments (Subsection 3.1.1.1 and Appendix B). Plutonium-238 (Pu-238) and, to a lesser extent, americium-241 (Am-241) are the major contributors to the total radionuclide content of CH TRU waste. Pu-238 waste has a higher curie content and heat-generating capacity than waste assumed in the FEIS analyses. The FEIS did not consider neutron dose rates; a small amount of such neutron-emitting waste containing californium-252 (Cf-252) may be disposed of at the WIPP.

- Experiments using high-level waste are no longer proposed for the WIPP.

- Consideration of the hazardous chemical constituents of the TRU waste inventory (Subsection 3.1.1.2). It is estimated that approximately 60 percent of the TRU waste that may be emplaced in the WIPP contains hazardous chemical constituents as defined by the Resource Conservation and Recovery Act (RCRA). However, the hazardous chemical constituents of this radioactive mixed waste constitute only a small fraction of the total waste and consist primarily of metallic lead from radiation shielding and residual quantities of organic solvents.

- Changes in the modes of transportation (Subsection 3.1.1.3). In the FEIS, it was anticipated that a mixed transport mode (75 percent train and 25

TABLE 3.2 Estimated volumes of RH TRU waste in retrievable storage or projected to be generated through the year 2013

Waste facility[b]	Estimated volume (ft^3)[a]		
	Retrievably stored waste[c]	Newly generated waste[d]	Total
Idaho National Engineering Laboratory	985	4,820	5,805
Hanford Reservation	848	28,600	29,448
Los Alamos National Laboratory	1,020	191	1,211
Oak Ridge National Laboratory	45,478	9,540	55,018
Argonne National Laboratory--East[e]	0	3,500	3,500
TOTAL	48,331	46,651	94,982

[a] Estimated volumes correspond to the Integrated Data Base for 1987 (DOE, 1987b). The volumes of waste used for the environmental analyses in this SEIS are higher and are based on the design capacity of the WIPP.

[b] Unless otherwise indicated, these sites both generate RH TRU waste and are designated TRU waste storage facilities.

[c] Stored as of December 31, 1986. From Table 3.5 in the Integrated Data Base for 1987 (DOE, 1987b).

[d] Generated from 1987 through 2013. From Table 3.16 in the Integrated Data Base for 1987 (DOE, 1987b).

[e] Facility that generates but does not store RH TRU waste.

percent truck) would be used. This SEIS considers transport by truck (100 percent), or "maximum" train mode (i.e., train transport from eight facilities and truck transport from Los Alamos National Laboratory and the Nevada Test Site, as they lack railheads). The use of 100-percent truck transportation is currently expected during the Test Phase; the train option could be used in combination with trucks in the future and, thus, is analyzed as an option in this SEIS.

- Changes in the waste packaging (Subsection 3.1.1.3). The design of the CH TRU waste transport packaging has changed from a vented, singly-contained rectangular (TRUPACT-I) packaging in 1987 to a nonvented, doubly-contained cylindrical (TRUPACT-II) packaging certified as a Type B packaging by the NRC on August 30, 1989.

- Implementation of a modified Test Phase (Subsection 3.1.1.4 and Appendix O). The technical focus of the Test Phase is to 1) reduce uncertainties associated with two primary factors that may affect repository performance: gas generation and brine inflow, and 2) demonstrate waste handling operations. For purposes of analysis, this SEIS assumes that a maximum of 10 percent of the WIPP TRU waste capacity might be retrievably emplaced during the Test Phase. The actual volume would be the minimum amount of waste to achieve the objectives of the Test Phase and is likely to be less than the amount assumed in this SEIS. The impacts of a Test Phase emplacing waste constituting a smaller volume would be proportionally reduced and would be bounded by the analysis in this SEIS.

The following changes (or new circumstances) are described in greater detail.

3.1.1.1 Transuranic Radionuclide Inventory. The types and quantities of radionuclides in the TRU waste that may be disposed of in the WIPP are collectively termed the "radionuclide waste inventory." Changes in the TRU radionuclide waste inventory involve the amount and type of radioactive material. These changes warrant discussion because they relate directly to the analyses of the potential environmental consequences of transporting waste to the WIPP (Subsection 5.2.2), WIPP operations (Subsection 5.2.3), and WIPP performance after closure (Subsection 5.4). These changes are described below and are further documented in the draft Final Safety Analysis Report (FSAR), Waste Isolation Pilot Plant (DOE, 1989a).

Since publication of the FEIS, techniques have been developed to better characterize the TRU waste generated at DOE defense program facilities. Sampling and measurement of waste by radiography, nuclear assaying, and other methods, and more stringent tracking and record keeping requirements have resulted in a better estimate of defense program TRU waste. In addition, the definition of TRU waste has changed. Prior to 1982, TRU waste was defined as having greater than 10 nCi/g of alpha-emitting radionuclides; TRU waste is presently defined as having greater than 100 nCi/g of alpha-emitting radionuclides and a half-life greater than 20 years. This redefinition was formalized in DOE Order 5820, "Radioactive Waste Management," in February 1984. This change has resulted in the reclassification of certain waste containing alpha emitting radionuclides, less than 100 nCi/g but greater than 10 nCi/g, to low-level

waste, which the DOE does not propose to dispose of in the WIPP. The Environmental Protection Agency (EPA) has adopted this definition of TRU waste. [For the EPA definition of TRU waste, see 40 CFR 191.02 (i).]

The waste characteristics given in Appendix E of the FEIS were based on TRU waste from the Rocky Flats Plant in Colorado because this waste was representative of all TRU waste proposed for disposal at the WIPP in 1980. The SEIS analyses are based on the more current waste characterization data reported for each generator facility in the draft FSAR. These data indicate that surface dose rates, curie content, total plutonium content, and fissile material for CH TRU waste have increased over comparable estimates in the FEIS (Table 3.3); except for surface dose rates and curie content, similar increases were noted for RH TRU waste. The TRU waste that may be shipped to the WIPP typically contains a variety of plutonium isotopes, as described in the FEIS (Appendix E). The average plutonium isotopic content of the waste as reported in the FEIS is compared to those in the draft FSAR and in Appendix B of this SEIS. The plutonium contents reported in the draft FSAR are generally greater than those reported in the FEIS.

Since publication of the FEIS, the DOE has determined that the radioisotopes Pu-238 and, to a lesser extent, Am-241 are the major contributors to the total radionuclide content of CH TRU waste, primarily due to waste generated at the Savannah River Site in South Carolina (DOE, 1988a). This waste has a higher curie content and heat-generating capacity than the waste described in the FEIS analyses. The average Pu-238 content reported in the FEIS is 1.2 percent of the total radioactivity content of CH TRU waste. TRU waste from the Savannah River Site increases the Pu-238 content of all CH TRU waste to 46 percent. The higher proportion of Pu-238 and Am-241 in the total waste has modified the average radionuclide composition of the "source term" (i.e., the actual amount of radioactivity potentially available for release) used to evaluate radiation dose consequences in this SEIS. High-curie content waste would be subject to the same surface dose equivalent rate restrictions as other waste; therefore, no unique handling, storage procedures, or precautions would be required for the high-curie waste.

The FEIS did not address neutron dose rates because neutron emitters were not identified in the waste that might be shipped to the WIPP. However, in the future, the Oak Ridge National Laboratory in Tennessee may contribute a small amount of waste to the WIPP containing californium-252 (Cf-252), which decays by spontaneous fission (DOE, 1989a). Almost 0.76 percent of the total RH TRU waste radioactivity would be composed of Cf-252. Neutron-emitting waste would be subject to the same surface dose rate restrictions as other waste; therefore, no unique handling, storage procedures, or precautions would be required for the high-neutron waste.

The FEIS discussed high-level waste experiments in Subsections 5.1.3, 6.3.3, 6.5.3, and 8.9 (see also FEIS Appendix E). An isolated area of the WIPP underground facility was to be dedicated to experiments determining the long-term behavior of various waste forms in bedded salt. The FEIS suggested that much of this waste would be specifically prepared for experiments and would produce high levels of heat and radiation.

TABLE 3.3 Summary of average TRU waste characteristics[a]

Characteristic[b]	CH TRU waste		RH TRU waste	
	FEIS[c]	FSAR[d]	FEIS[c]	FSAR[d]
Surface dose rate (millirem per hour)[e]				
Drum	3.1	14		
Standard waste box	1.0	14		
Canister			200-100,000	30,000
Thermal power (watts)[f]				
Drum (maximum)	0.5	0.5		
Standard waste box (maximum)	0.8	0.8		
Canister (average)			70	60
Radioactivity (curies)				
Drum	3.4	20.6		
Standard waste box	5.5	77		
Canister			260[g]	37[g]
Total plutonium content (g)				
Drum	8	15.5		
Standard waste box		13	86.3	
Canister			12.8	120
Fissile material content[h]				
Drum	7.5	17		
Standard waste box	12.2	90		
Canister			12	110

[a] The reasons for the differences between the FEIS and the FSAR values are discussed in Appendix B.1.
[b] For a description of waste containers, see Appendices A and L.
[c] From the WIPP FEIS (DOE, 1980).
[d] From the WIPP draft FSAR (DOE, 1989a). These values were also used in the SEIS.
[e] The radiation exposure rate at the outside surface of the package.
[f] The heat-generating capability of the radionuclides.
[g] Radioactive decay products are not included. Average radioactivity per container as reported by facilities. The maximum plutonium-239-equivalent curie (PE-Ci) activity per container is 1,000 PE-Ci (DOE, 1989b).
[h] Expressed as the plutonium-239-equivalent fissile content in g. For materials other than plutonium-239, uranium-235, and uranium-233, which are treated as equivalent, fissile equivalents are calculated in accordance with Standard ANSI/ANS-8.15-1981 of the American National Standards Institute and the American Nuclear Society.

The need for conducting high-level waste experiments at the WIPP has been reassessed, and the DOE has decided to eliminate this aspect of the WIPP project. This decision was based principally on the decision under the Nuclear Waste Policy Amendments Act of 1987 to discontinue further characterization of the Deaf Smith County, Texas, bedded salt site for the disposal of commercial high-level waste. Therefore, the DOE is not proposing to emplace high-level waste in the WIPP for experimental purposes.

3.1.1.2 Hazardous Chemical Constituents. Radioactive waste that also contains hazardous chemical constituents as defined by RCRA is termed radioactive mixed waste. The FEIS did not separately address the hazardous waste components of TRU mixed waste, even though it was known that it would comprise a certain portion of the total waste to be shipped to the WIPP. This SEIS includes analyses of the potential environmental consequences of the hazardous chemical constituents in the TRU mixed waste.

Because of the complex waste matrices and potential for unacceptable radiation exposure to personnel, sampling of stored drums is not an acceptable way to characterize the waste. Instead, knowledge of the waste and the processes from which it is derived has been used to characterize the waste as provided by 40 CFR 262.11 (c) (2). (However, waste to be used for the bin-scale tests would be analytically characterized.) The requirements of strict product quality and concerns for safety in handling radioactive material demand highly structured production and research activities. Accordingly, information on the chemicals used and processes that generate these wastes has enabled the DOE to identify the type, forms, and extent of hazardous constituents.

The 10 defense program facilities that may transport waste to the WIPP have conservatively characterized their TRU mixed waste to facilitate preparation of the permit application to operate the WIPP as an interim status facility under the RCRA. This information was reported by the Westinghouse Electric Corporation (WEC, 1989) and represents a conservative upper bound in classifying the waste.

The identification of the hazardous chemical constituents in CH TRU mixed waste is based on knowledge of the characteristics of newly generated waste from the Rocky Flats Plant in Colorado and Rocky Flats Plant waste that is currently in retrievable storage at the Idaho National Engineering Laboratory in Idaho. The Rocky Flats Plant generates many different forms of waste from a variety of processes. Based on data submitted by the generators of TRU mixed waste (WEC, 1989), other facilities generate smaller quantities of TRU mixed waste, fewer waste forms, and waste that contains a narrower range of hazardous chemical constituents. Also, no hazardous chemical constituents were reported by other facilities that were not reported by the Rocky Flats Plant and the Idaho National Engineering Laboratory. In addition, this waste represents approximately 86 percent, by volume, of the total CH TRU mixed waste that may be disposed of in the WIPP over 25 years of operation. For these reasons, the DOE believes this waste to be representative of all CH TRU mixed waste.

The CH TRU waste is categorized into waste "forms" on the basis of the physical characteristics of the materials in the waste. Each waste form must be certified by the

DOE for compliance with the WIPP WAC (Subsection 2.4.1 and Appendix A) before shipment to the WIPP. The waste forms that have been identified by the Rocky Flats Plant as containing hazardous chemical constituents are cemented and uncemented aqueous and organic waste, immobilized process and laboratory solids, combustible waste, metal and filter waste, inorganic solids, and leaded rubber waste. Detailed descriptions of these waste forms, provided in Appendix B, indicate that the majority of the organic solvents are present in residual quantities from the cleaning of equipment, plastics, glassware, and filters. A major hazardous constituent in CH TRU mixed waste is lead, which is present predominantly as shielding, glovebox parts, and lead-lined gloves and aprons.

The types and estimated maximum concentrations of hazardous chemical constituents in the CH TRU mixed waste forms are provided in Table 3.4. These concentrations, as estimated by the Rocky Flats Plant (Rockwell International, 1988), represent the maximum concentrations expected in the waste forms. The DOT requires generators to document the concentrations of hazardous materials over reportable quantities (49 CFR 172.101) on the shipping documents that accompany the waste during transport. Transportation of these wastes is also governed by the EPA under RCRA (40 CFR Parts 262, 263.) The Rocky Flats Plant has reported the maximum expected concentrations based on process knowledge. The data indicate a broad range of concentrations of the various constituents, both within and between waste forms. They also indicate that the majority of the waste forms contain less than 1 percent by weight of any of the identified hazardous chemical constituents.

RH TRU waste is a much smaller portion of the total waste that may be sent to the WIPP (Subsection 2.3). The Oak Ridge National Laboratory generates more than 90 percent of the RH TRU mixed waste and has reported that the two major forms of RH TRU mixed waste are solids and sludges (Appendix B) (DOE, 1987b). The primary hazardous chemical constituent in the RH TRU mixed waste is lead that has been used as shielding. Trace quantities of mercury, barium, chromium, and nickel have also been reported in some of the sludges.

3.1.1.3 Transportation of TRU Waste to the WIPP. Section 6 of the 1980 FEIS described the main features of transporting radioactive TRU waste to the WIPP, including the DOT and NRC regulations governing transport, the packages and packaging systems to be used for the waste, and the typical transportation modes and routes. Since that time, there have been changes in the waste packaging systems and the transportation modes and routes; these changes directly affect the analyses of the environmental consequences of waste transportation that are presented in Subsection 5.2.2.

This subsection describes the changes in the waste packaging systems and transportation modes and routes. Additional details are provided in Appendices C, D, L, and M. The 1980 FEIS defined "packaging" as the shipping container for radioactive waste and "package" as the shipping container and its radioactive contents. These same definitions apply to these terms when used in this SEIS.

Waste Transportation Packaging. In 1987, the DOE agreed to ask the NRC to certify the designs of the shipping containers used for the transport of TRU waste to WIPP.

TABLE 3.4 Estimated maximum concentrations of hazardous chemical constituents in TRU mixed waste from the Rocky Flats Plant[a]

Hazardous chemical[c] constituent	Waste form[b]							
	Aqueous sludges[d]	Organic sludges[d]	Process and laboratory solids[e]	Combustible waste	Metal waste	Filter waste	Inorganic solids	Leaded rubber
1,1,1-trichloroethane	75	150,000	200	2,000	15	150	900	0
Carbon tetrachloride	25	50,000	25	750	10	150	100	0
1,1,2-trichloro-1,2,2-trifluoroethane	100	50,000	200	1,500	75	100	8,000	0
Methylene chloride	700	0	100	750	200	50	700	0
Methyl alcohol	25	0	15	0	0	0	0	0
Xylene	50	0	50	0	0	0	0	0
Butyl alcohol	10	0	10	0	0	0	0	0
Cadmium	10	0	0	0	0	0	0	0
Lead	10	0	400	10	1,000,000	0	0	600,000

[a] Estimated maximum concentrations in milligrams per kilogram (mg/kg) (Rockwell International, 1988).
[b] Waste forms are described in detail in Appendix B.
[c] The hazardous chemical constituents were determined by knowledge of the processes used in generating the waste. The estimated maximum concentrations represent conservative (i.e., overestimated) quantities that may be present in the specific waste forms. No analytical data are available for the hazardous chemical constituents in these waste forms.
[d] Cemented and uncemented sludges.
[e] Neutralized and immobilized (cemented) solids.

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This agreement was stated in the second modification (August 4, 1987) to the Agreement for Consultation and Cooperation between the Department of Energy and the State of New Mexico on the Waste Isolation Pilot Plant.

Type B double-contained packagings are used for the transport of TRU waste containing over 20 curies of plutonium. In order to be certified by the NRC as Type B (10 CFR 71.73), a packaging must undergo evaluations related to normal transportation conditions (described in Appendix L) and hypothetical accident scenarios, which are listed below:

1) Free drop. A drop from a height of 30 ft onto a flat, unyielding surface, in a position for which maximum damage is expected.

2) Puncture. A drop from a height of 40 inches onto a 6-in diameter puncture bar in a position for which maximum damage is expected.

3) Thermal. Exposure to a fully engulfing fire with a minimum temperature of 1,475 degrees Fahrenheit for at least 30 minutes.

4) Immersion. Exposure to an external pressure equivalent to immersion under at least 50 ft of water for 8 hours.

These tests are not meant to duplicate accidents, but to produce packaging damage equivalent to that observed in severe transportation accidents. The packaging must withstand these combined events without releasing more than a specified, very small portion of the radioactive contents. Additional details on Type B requirements are provided in Appendix L.2.3.1.

CH TRU Waste Transport. The packaging for transporting CH TRU waste to the WIPP is the TRUPACT-II. The TRUPACT-II is a reusable shipping packaging which has been certified by the NRC (August 30, 1989) as a Type B Package per 10 CFR Part 71. The NRC-issued Certificate of Compliance is annexed to Appendix L. Compliance with these regulations was demonstrated by a combination of full-scale testing and analysis.

The TRUPACT-II packaging is a circular cylinder with a flat bottom and a domed top that is transported in an upright position. The major components of the TRUPACT-II (Figure 3.1) are a sealed inner stainless steel containment vessel within a sealed outer stainless steel containment vessel. The inner and outer containment vessels have removable lids that are held in place by banded lockrings and retaining tabs. Each containment vessel is nonvented and capable of operating at an internal gauge pressure of 50 pounds per square inch (psig). The inner containment vessel contains the waste payload. The payload is protected by spacers that are made of aluminum honeycomb and are located in each of the domed heads of the inner vessel.

The outer containment vessel is surrounded by approximately 10 inches of fire-retardant polyurethane foam acting as a thermal insulator and two 1/4-inch layers of ceramic fiber for additional thermal insulation. On the outside of this foam and ceramic fiber, external to the containment, is a stainless steel shell that acts as a protective structure as well as an impact limiter. This multi-layered wall design increases the overall packaging strength and provides the ability to withstand potential accidents associated with transport.

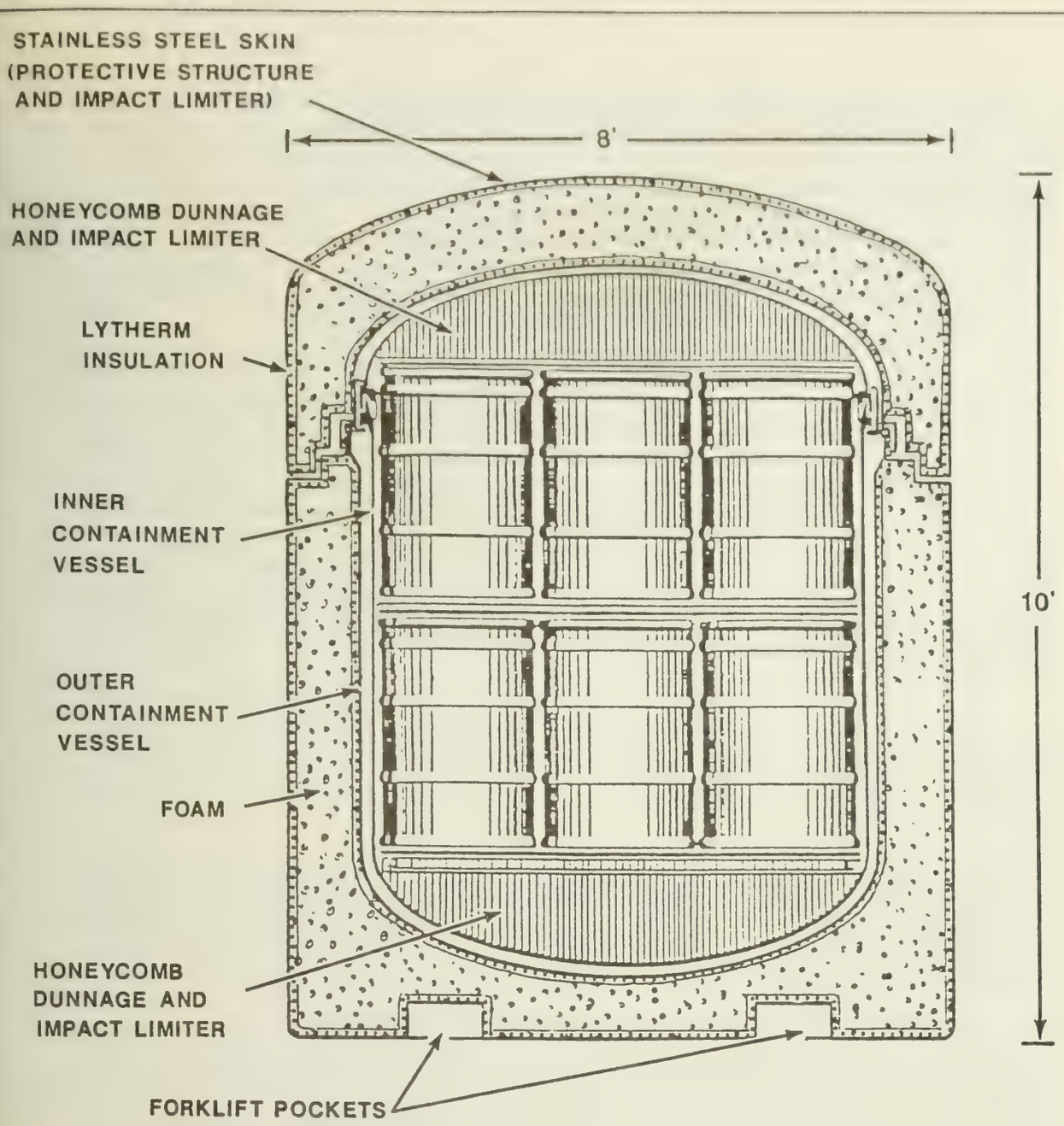

FIGURE 3.1
CROSS SECTION OF TRUPACT-II

The overall dimensions of the TRUPACT-II are approximately 8 ft in diameter by 10 ft high; the inner containment vessel is approximately 6 ft in diameter by 8 ft high. The capacity of each TRUPACT-II packaging is 7,265 pounds of payload packed in either fourteen 55-gal drums or two 67 cubic ft standard waste boxes (SWB). The maximum gross shipping weight of a TRUPACT-II shipping package is 19,250 pounds to meet highway load restrictions. Three TRUPACT-II packages are transported on a custom designed semi-trailer which is pulled by a conventional tractor for highway travel. Additional details on the TRUPACT-II design and related equipment are provided in Appendices L and M.

Table 3.5 summarizes the test sequence of the three full-scale TRUPACT-II certification test units compared to the requirements for evaluating the packaging under hypothetical accident conditions as stated in the NRC Regulations (10 CFR 71.73). As shown in this table, the number of drop and puncture tests performed on each certification test unit exceeded the regulatory requirements in many cases; this was done to confirm that the package could sustain impact in a variety of "worst case" orientations and remain leaktight. For example, each of the 30-ft drops on test units 1 and 2 were performed with the different sections of the TRUPACT-II impacting the unyielding surface (i.e., lockrings, tiedown areas, etc.). In addition to the hypothetical accident condition testing, a 3-ft handling drop was performed on unit 1 to satisfy one of the requirements for evaluating normal transport conditions. Additional details on the testing of TRUPACT-IIs are provided in Appendix L.

A decision to pursue certification for rail transport would be made after the DOE has fully evaluated the option of rail transport for TRU waste. Some design features of the TRUPACT-II (e.g., the tiedown system for attaching the packaging to a railcar) may have to be modified for rail transport.

Type A packagings will generally be used inside TRUPACT-II packaging for the transport of CH TRU waste to the WIPP. Type A packagings must meet the requirements of 49 CFR 178.350, including evidence that the design can withstand the normal conditions of transport as defined in 49 CFR 173.465 and 173.466. Related evaluations involve exposure of the packaging to simulated rainfall, free fall, compression, and penetration.

The Type A waste packagings to be transported within the TRUPACT-II are normally expected to be Type A 55-gal drums or SWBs. The 55-gal drums are constructed of 16-gauge steel and may have liners of 90-mil, high-density polyethylene; the drums have removable lids retained by bolted rings while the liners have snap-fit lids or bolted rings. Each drum normally measures 24 inches in diameter by 35 inches high. The drums will be grouped into "7-packs" (seven drums banded together by metal banding or plastic stretch wrap). Each SWB will measure approximately 71 inches in diameter with two flat sides measuring 54 inches wide by 37 inches high (i.e., rectangular in shape with rounded ends) (Figure 3.1A).

RH TRU Waste Transport. The 1980 FEIS did not propose a specific type of packaging for transporting RH TRU waste to the WIPP, but implied that this packaging would comply with Type B requirements and would be shielded as necessary. The DOE is now developing the Nuclear Packaging 72B (NuPac 72B) for the transportation of RH TRU

TABLE 3.5 Minimum regulatory testing requirements versus actual TRUPACT-II certification testing program

Test	Requirement[a]	Number of tests		
		Unit 1	Unit 2	Unit 3
Free drop	1	3	3	3
Puncture	1	5	6	5
Thermal	1	1	1	0
Immersion	1	1[b]	1[b]	1[b]

[a] From 10 CFR 71.73; requirements can be met by test or analysis.

[b] Note: One analysis used to support all three test units.

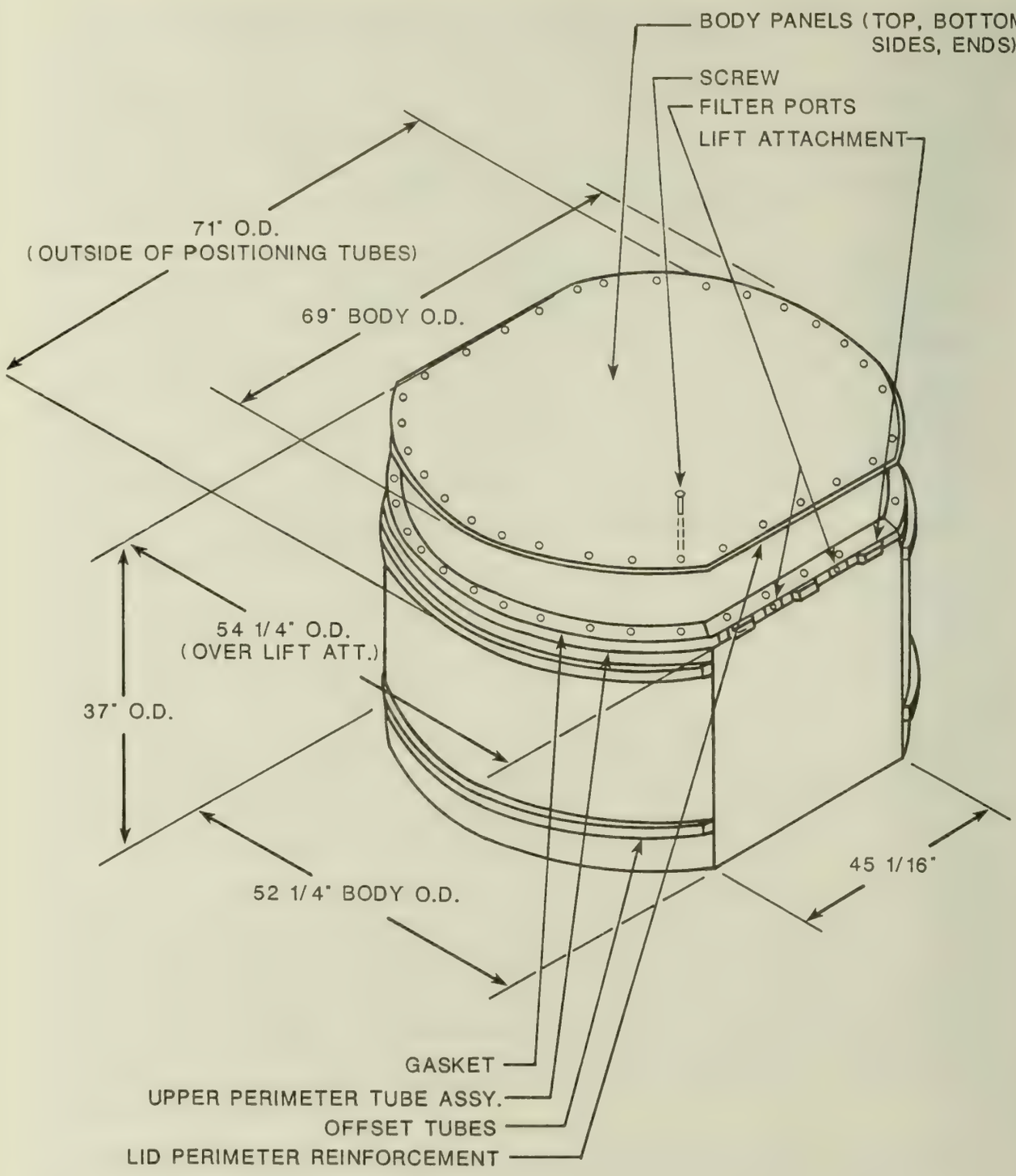

FIGURE 3.1a
STANDARD WASTE BOX

waste. Compliance with the NRC requirements for Type B packaging has to be demonstrated for the 72B cask by analysis, or by combination of analysis and testing. The 72B cask is a scaled-down version of the 125B package which has been certified by the NRC as a Type B package. Hence analysis will be the primary method of demonstrating compliance with regulations for the 72B cask. The NuPac 72B cask will be certified by the NRC (expected in early 1990s) before DOE will use it to transport RH TRU waste to the WIPP. The NuPac 72B (Figure 3.2) is designed with cylindrical outer and inner stainless steel containment vessels that will be transported horizontally. Neither containment vessel is vented and each is capable of withstanding an internal pressure of 150 pounds per square inch (gauge). The capacity of the 72B cask is 8,000 pounds of payload. The payload consists of the RH TRU waste packed in 30- or 55-gal drums which are contained in a carbon steel canister.

The inner containment vessel provides a cavity for the carbon steel canister which is approximately 26.5 inches in diameter and 123 inches long. The lid is secured to the body of the inner containment vessel by means of eight closure bolts. Internal spacers are provided at the top, bottom, and at two locations near the middle of the inner vessel to center the canister and to facilitate the insertion and removal of the canister. The outer cask vessel is constructed of two concentric shells enclosing a cast-lead shield. The shield is for gamma radiation and is approximately 1.9 inches thick. The outer cask is approximately 142 inches long and has an outer diameter of 42 inches. It is protected at each end by energy-absorbing impact limiters, which are stainless-steel shells filled with polyurethane foam. The impact limiters also act as thermal insulators to protect seal areas from fire during an accident.

Transportation Modes. The 1980 FEIS considered transportation of TRU waste to the WIPP by a combination of truck and rail transport (75 percent rail and 25 percent truck). The DOE currently proposes to use 100 percent truck transportation during the Test Phase, but has not dismissed using rail transportation during the Disposal Phase. Shipping by truck during the Test Phase is proposed because rail transport would cost more (larger inventory of TRUPACT-IIs is needed) and would not provide the control (rail could require use of multiple commercial carriers) necessary to manage the program effectively. Also, as discussed below, the DOE has not initiated the process for obtaining NRC certification of Type B packagings for rail transport of CH and RH TRU waste. However, the DOE would consider the feasibility of using rail transport to ship TRU waste to the WIPP during the Disposal Phase.

This SEIS, however, considers two transportation modes: truck transport and maximum rail transport. The truck transport mode assumes shipping all TRU waste to the WIPP by truck; the maximum rail transport mode assumes shipping TRU waste to the WIPP by rail from eight defense program facilities that now have railroad access and by truck from the two defense program facilities that do not have railroad access. This approach bounds the impacts from any combination of shipping modes that the DOE may select in the future for the TRU waste that may be disposed of at the WIPP.

The CH TRU waste would be trucked to the WIPP in TRUPACT-II packagings mounted on specially designed trailers pulled by diesel-powered tractors (Figure 3.3). These tractor-trailer combinations are similar to those now used for commercial purposes;

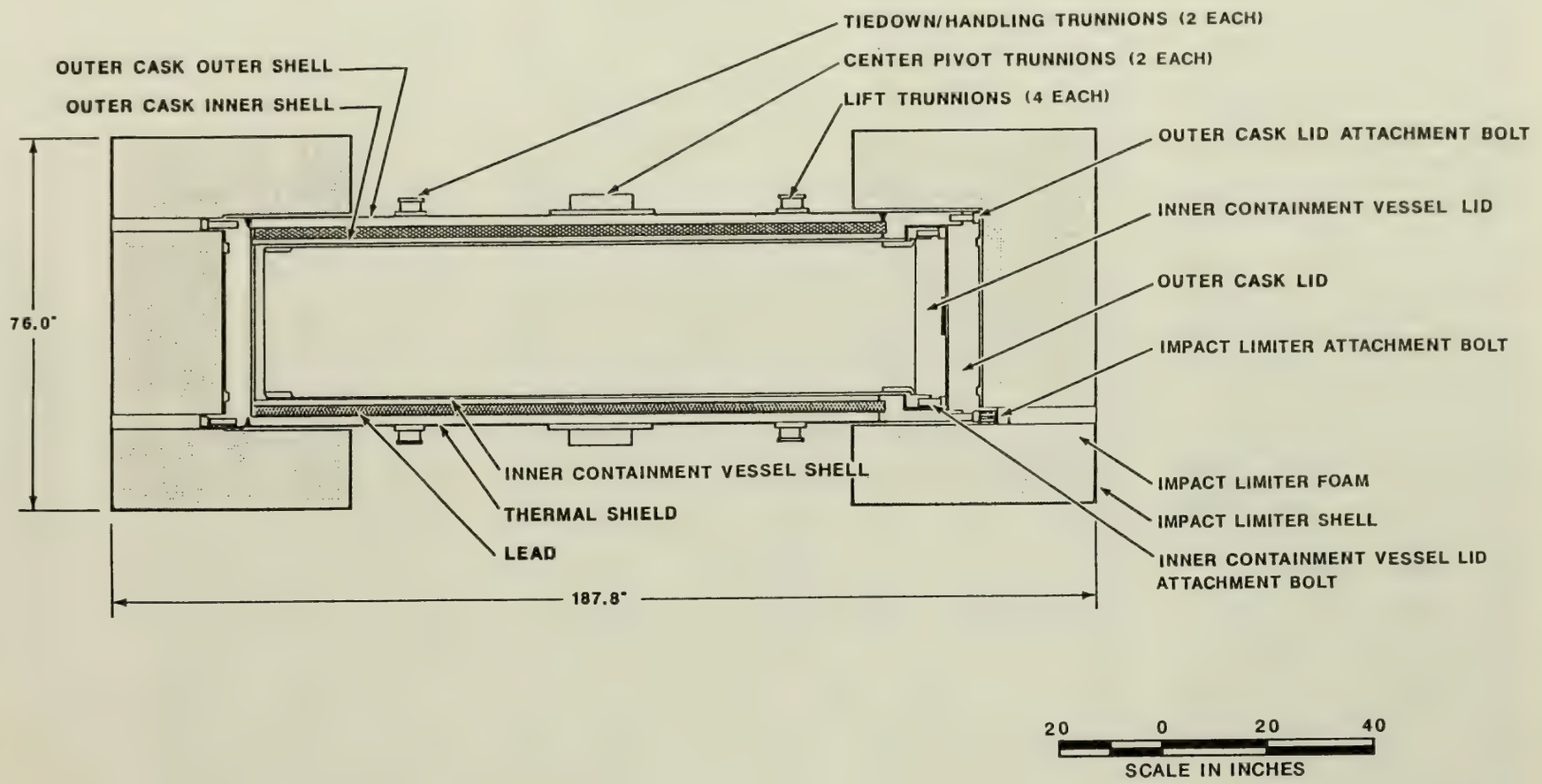

FIGURE 3.2
CROSS SECTION OF NUPAC 72B CASK

however, they have been specially designed to carry three TRUPACT-II packagings per trailer, and they have other special features such as a two-way communications system and road speed limiters (governors). In 1988, the DOE awarded a contract to a commercial carrier for the first 3 years (with 2 one-year options) of truck transport of TRU waste to the WIPP. This detailed contract includes the design specifications for the tractor; requirements for driver qualifications and training; equipment maintenance; maintenance facilities and records; and procedures for TRU waste transportation, mechanical failures, and emergencies (Appendix M). The commercial carrier is responsible for providing a contract manager, a tractor fleet, and qualified drivers that are dedicated solely to this TRU waste transportation contract. Prototypes of the tractor-trailer and TRUPACT-II packagings with simulated, nonradioactive waste cargo have been road tested. The requirements of the trucking contract in all these areas are highly specific and demanding.

An important feature of the truck transport mode is the Transportation Tracking and Communications System (TRANSCOM) that would be used to provide control and more efficient transport of TRU waste to the WIPP. The TRANSCOM (Figure 3.4) would combine navigation, satellite communication, and computer network technologies to monitor the movement of TRU waste shipments to the WIPP. Each tractor-trailer will be equipped with a two-way communications system in the tractor cab. A Loran C antenna and a satellite antenna will be mounted on the trailer. Each tractor-trailer would automatically send a signal every 15 minutes to update its geographical location and status and to verify that the established transportation route is being followed. The system will provide the nearest emergency points of contact (i.e., police, highway patrol, and emergency operation centers) should an emergency or mechanical failure occur. The TRANSCOM system and driver qualifications and training would provide shipment security. The drivers would be trained how to respond to threats of sabotage or terroism and how to handle incidents that might occur. Although the possibility for acts of sabotage or terrorism involving TRU waste shipments cannot be predicted, the DOE has incorporated important deterrents in the TRU waste transportation program to counter such actions. These deterrents reduce the attraction of using TRU waste shipments as targets for sabotage or terrorism. A detailed description of TRANSCOM is provided in Appendices D and M.

The DOE is committed to using the TRANSCOM 24 hours per day to enhance the DOE management capabilities, emergency response, and efficient transport of TRU waste to the WIPP. The TRANSCOM Control Center (TCC) has developed a computer network and data base that provides easy access to shipment information. The system is designed to provide both DOE users (i.e., storage and generator facilities) and approved non-DOE users (i.e., involved State and Tribal governments) access to the TCC via personal computers. The system's computer software has been developed, and a commercial satellite telecommunication system has been selected. Tests have been conducted using tractor-trailer combinations and TRUPACT-II containers (without TRU waste) to verify the effectiveness of the TRANSCOM system.

As discussed above, the DOE is now developing a Type B packaging (NuPac 72B) for the transportation of RH TRU waste to the WIPP. The trailers for the NuPac 72B cask are in the design stage. There would be one cask per trailer. It is expected that the cask would be transported by the same tractors and monitored in the same way as the TRUPACT-II shipments.

Transportation Routes. This SEIS analyzes the environmental consequences of waste transportation from ten storage and generator facilities. The analysis considers the two transportation modes previously described (truck and maximum rail transport), and the typical transportation routes between the storage and generator facilities and the WIPP for these two modes.

U.S. Department of Transportation (DOT) regulations in 49 CFR 177.825 provide a routing rule for highway route controlled quantities of radioactive materials (WIPP shipments fall into this category). This routing rule permits States and Indian Tribes to designate routes in accordance with DOT guidelines or an equivalent routing analysis. Interstate highways must be used in the absence of a State-or Tribal-designated route unless a deviation is necessary. Currently, there are DOT requirements for shipment of radioactive material by rail.

The proposed routes for truck transport of TRU waste from the 10 defense program facilities to the WIPP are shown on Figure 3.5. These routes use the interstate highway system to the maximum extent reasonably possible; however, because there is not direct access to interstate highways from all facilities, as well as to the WIPP, Federal, State, or local highways would be used as necessary. Where available, TRU waste shipments would use beltways around urban areas. Detailed route descriptions from each defense facility to the WIPP are provided in Appendix D.

Each of the 23 corridor States was contacted to provide a qualitative assessment of road segments of concern along the proposed route in their State. In general, reported segments of concern are related to weather conditions, rush-hour traffic in larger urban areas, or miscellaneous road features (e.g., dangerous curves). Table D.2.1 (Appendix D) provides a summary of the reported segments of concern. The DOE will provide the carrier with this information. Because many of the concerns are related to winter driving conditions in the mountains, parking areas may be designated in cooperation with the corridor State, as appropriate.

The highway mileage for the DOT-approved truck transportation routes is provided in Table 3.6. As noted in the table, the range of highway mileage accounts for alternative routes or detours that could be required due to traffic accidents, highway maintenance, or adverse weather conditions. The average highway mileage is a conservative transportation distance that includes some alternate routes and detours; this mileage was used in this SEIS to analyze the environmental consequences of TRU waste transportation to the WIPP.

Figure 3.6 shows typical rail transportation routes to the WIPP from the eight generator facilities that presently have railroad access. As previously noted, these routes are not required to be approved by the DOT for the shipment of TRU waste. The mileage for the typical rail transportation routes are provided in Table 3.7. As with the highway mileage for the DOT-approved truck transportation routes, these mileages account for alternate routes and detours that may be required during waste shipment.

Six mainline railroad companies have lines that would directly access eight of the ten defense program facilities: 1) the Atchison, Topeka and Santa Fe, 2) the Union Pacific (also owns Missouri Pacific), 3) Mid-South, 4) CSX Transport, 5) Southern, and 6)

Denver and Rio Grande Western. Only the Argonne National Laboratory in Illinois is on a direct line to the WIPP. Shipments from the other defense program facilities would require between one and five transfers.

3.1.1.4 Implementation of a Modified Test Phase. A part of the Proposed Action is to conduct a Test Phase of approximately 5 years. The Test Phase has two distinct elements: 1) the Performance Assessment, and 2) the Integrated Operations Demonstration. These elements continue to evolve. At this time, the Performance Assessment tests would be comprised of laboratory-scale, bin-scale, and alcove-scale tests. Currently, plans on such issues as waste source, type, and volumes for the initial phase of tests are nearing finalization (DOE, 1989c). Waste requirements for the integrated operations demonstration are currently undergoing review. In December 1989, the DOE published a detailed phased plan for the Test Phase (DOE, 1989c; also see Appendix O), that focused on the methods and activities required to demonstrate compliance with the long-term performance standard of 40 CFR 191, Subpart B. In addition, several of the tests planned for the Test Phase would provide data that would be used to support WIPP's demonstration that there would be no migration of hazardous constituents of the waste, as required under the RCRA Land Disposal Restrictions (40 CFR 268). A separate document would be developed to describe in detail the Integrated Operations Demonstration plan. As discussed below, the DOE believes that the analyses in this SEIS bound the potential impacts that would be estimated to arise from any waste requirements that might be planned for the Operations Demonstration.

During the Test Phase, the DOE proposes to transport to and emplace in the WIPP limited quantities of waste; the specific quantities of waste emplaced would be limited to that deemed necessary to achieve the objectives of the Test Phase. For purposes of bounding the potential impacts of the Test Phase in this SEIS, the DOE assumes that up to 10 percent of the volume of TRU waste that could ultimately be permanently emplaced at the WIPP would be emplaced during the Test Phase. The actual amount of waste proposed for the Test Phase is likely to be less than that assumed for purposes of analysis in this SEIS. It is also assumed for purposes of bounding the impacts that waste would be shipped from all 10 facilities, although it is now likely that only waste from the Rocky Flats Plant and the Idaho National Engineering Laboratory would be used during the initial phases of the proposed Test Phase.

Subsets of the Proposed Action include conducting the Test Phase with bin- and/or alcove-scale tests without the integrated operations demonstration and conducting these tests with a lesser volume of waste than assumed in the SEIS. The impacts of these subsets would be bounded by the analysis of the Proposed Action in this SEIS.

Any waste brought to the WIPP during the Test Phase would remain fully retrievable during this Test Phase period and for a reasonable period thereafter, and would be retrieved if a decision were made not to proceed to the Disposal Phase.

Performance Assessment. Following publication of the FEIS in 1980, the EPA promulgated standards in 40 CFR Part 191, Subpart B, for the permanent disposal of TRU waste. These standards were vacated and remanded to the EPA by a Federal Circuit Court of Appeals and are not expected to be repromulgated in final form until

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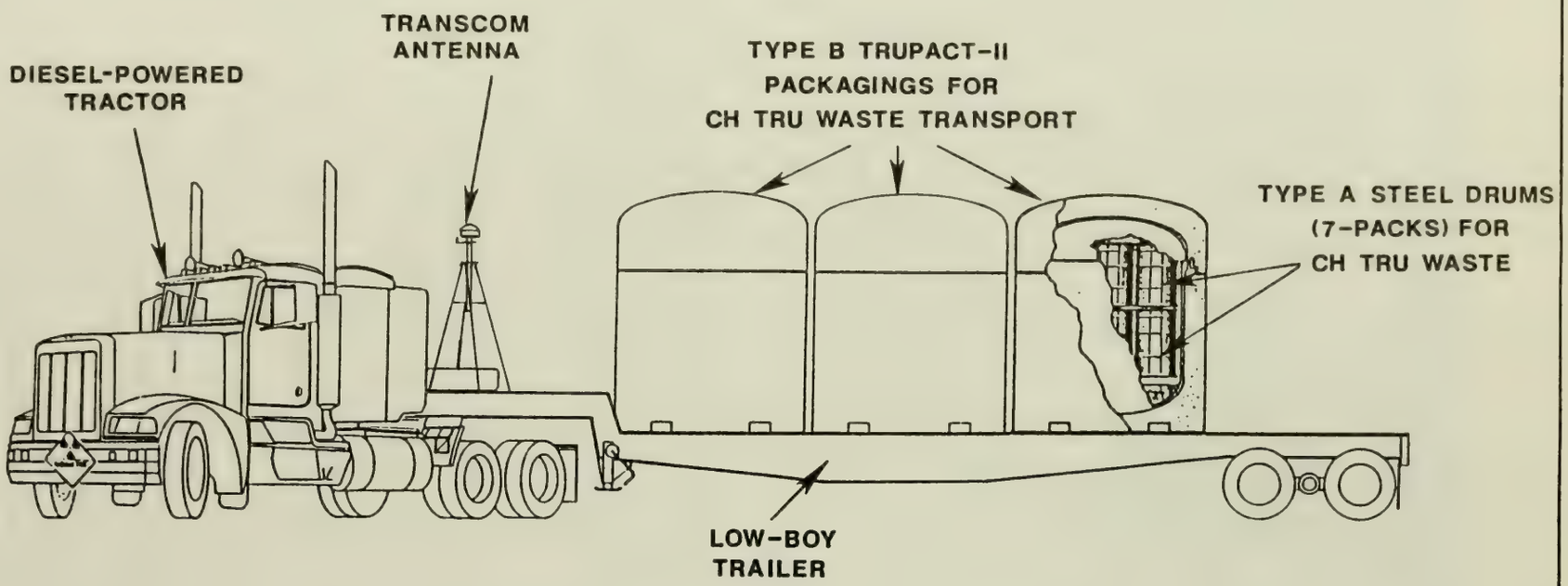

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FIGURE 3.3

TYPICAL TRACTOR-TRAILER COMBINATION FOR TRU WASTE TRANSPORT

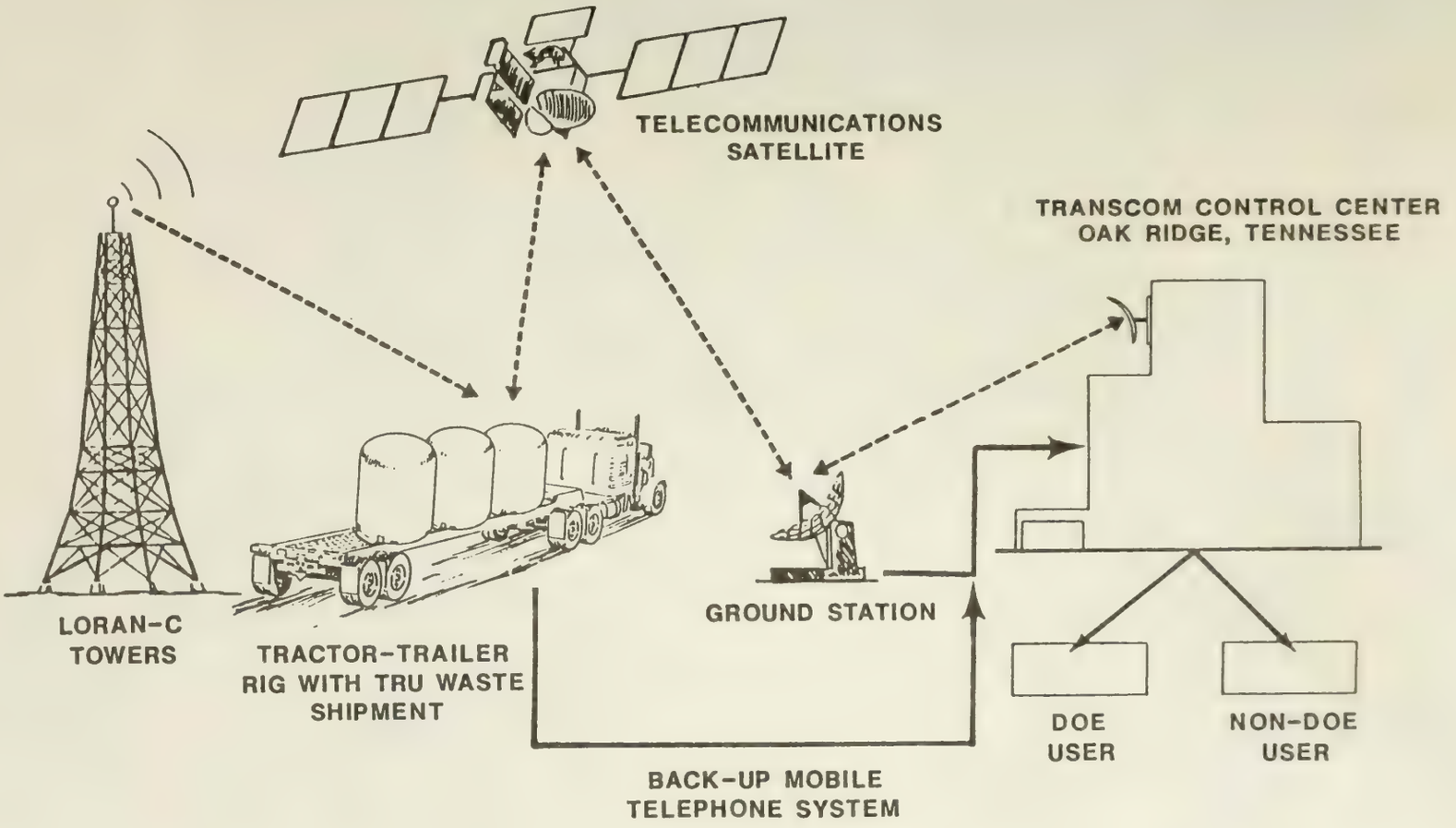

FIGURE 3.4
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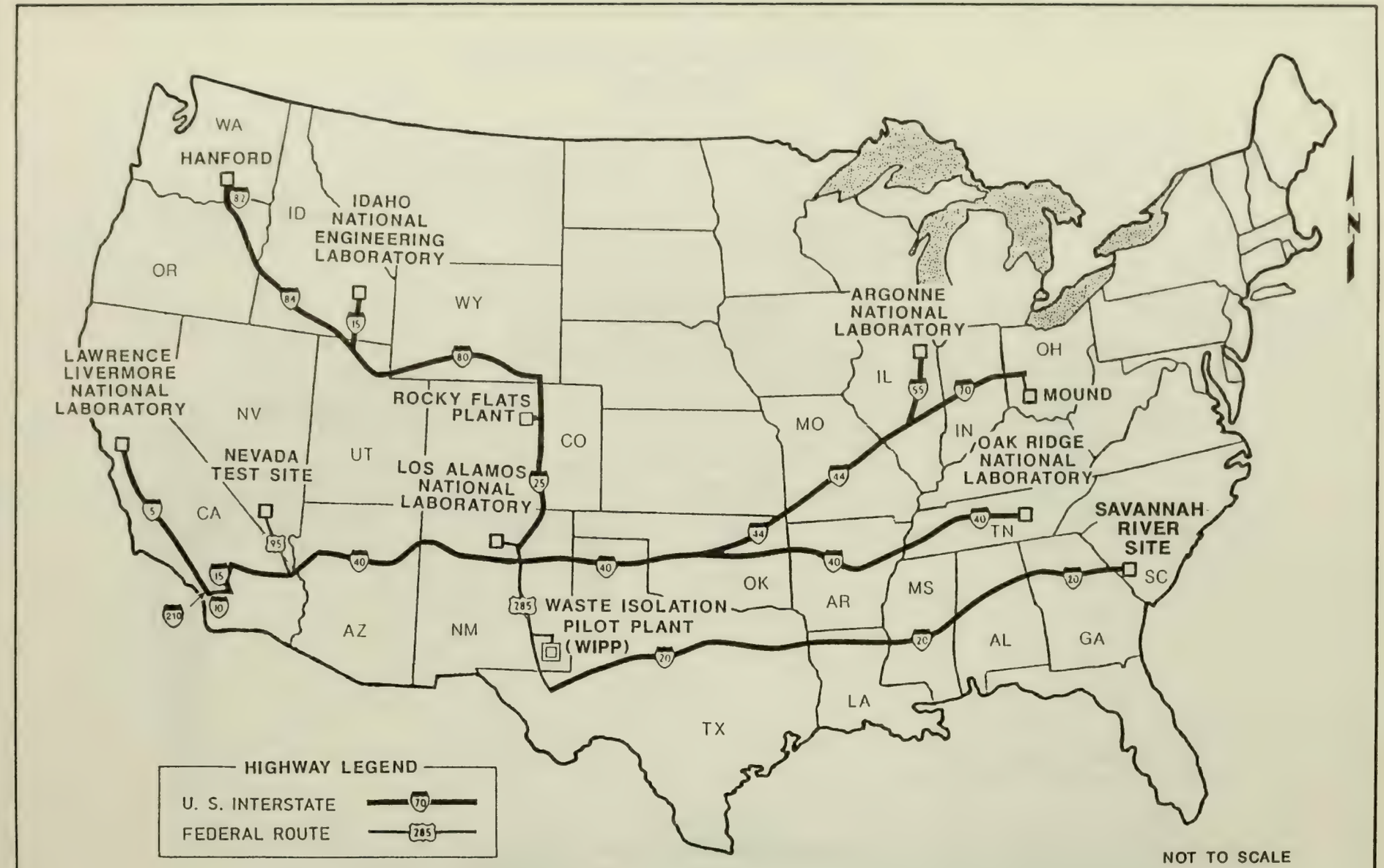

FIGURE 3.5
PROPOSED TRU WASTE TRUCK TRANSPORTATION ROUTES

TABLE 3.6 Highway mileage for DOT-approved truck transportation routes[a]

Storage or generator facility	Average highway mileage	Range of highway mileage
Idaho National Engineering Laboratory, Idaho	1521	1338-1771
Rocky Flats Plant, Colorado	874	749-1072
Hanford Reservation, Washington	1913	1745-2177
Savannah River Site, South Carolina	1585	1447-1663
Los Alamos National Laboratory, New Mexico	343	343
Oak Ridge National Laboratory, Tennessee	1350	1303-1393
Nevada Test Site, Nevada	1286	1024-1456
Argonne National Laboratory-East, Illinois	1387	1329-1419
Lawrence Livermore National Laboratory, California	1458	1370-1527
Mound Laboratory, Ohio	1472	1428-1511

[a] The range of highway mileage accounts for alternate routes and detours that may be required due to traffic accidents, route maintenance, or adverse weather conditions. The average highway mileage includes some alternate routes and detours; this distance was used to analyze the environmental consequences of TRU waste transportation to the WIPP (DOE, 1986).

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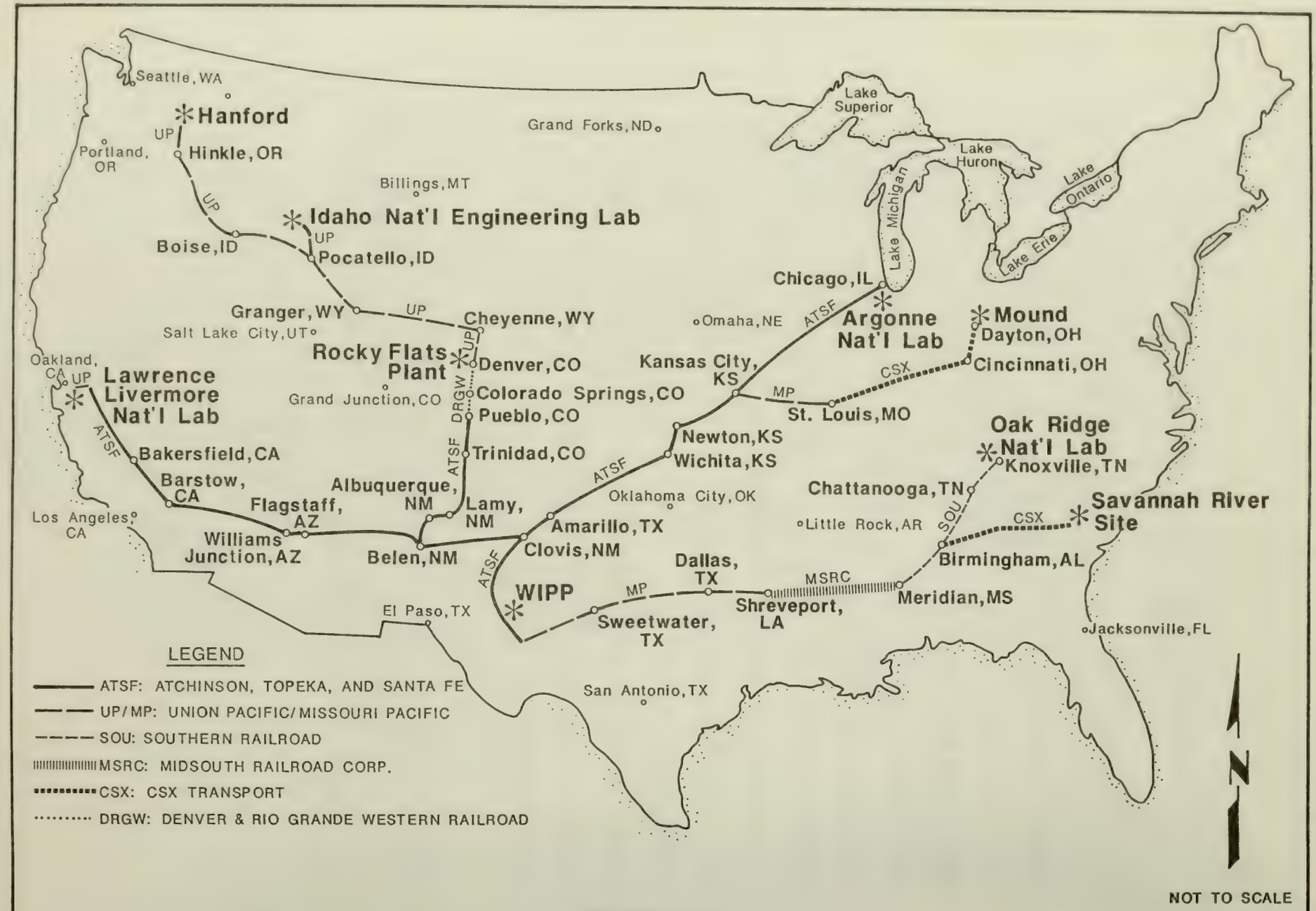

FIGURE 3.6
PROPOSED MAINLINE RAILROAD ROUTES FOR TRU WASTE TRANSPORTATION TO THE WIPP

TABLE 3.7 Railroad mileage for rail transportation routes[a]

Storage or generator facility	Average railroad mileage	Range of railroad mileage
Idaho National Engineering Laboratory, Idaho	1761	1466-2054
Rocky Flats Plant, Colorado	1098	748-1572
Hanford Reservation, Washington	2296	1992-2579
Savannah River Site, South Carolina	1915	1786-2074
Los Alamos National Laboratory, New Mexico	343	343[b]
Oak Ridge National Laboratory, Tennessee	1630	1552-1676
Nevada Test Site, Nevada	1286	1024-1456[b]
Argonne National Laboratory-East, Illinois	1469	1279-1658
Lawrence Livermore National Laboratory, California	1873	1657-2242
Mound Laboratory, Ohio	1677	1625-1726

[a] The range of railroad mileage accounts for alternate routes and detours that may be required due to accidents, route maintenance, or adverse weather conditions. The average railroad mileage includes some alternate routes and detours; this distance was used to analyze the environmental consequences of TRU waste transportation to the WIPP (DOE, 1986).

[b] At the present time, there is no railroad access to Los Alamos National Laboratory in New Mexico and the Nevada Test Site in Nevada. Only the environmental consequences of truck transportation of TRU waste from these sites to the WIPP were analyzed in this SEIS.

approximately 1991 or 1992. In the interim, the DOE has agreed with the State of New Mexico to proceed with its long-term performance assessment as if the standards were still in effect. The following paragraphs describe the performance assessment activity as now proposed.

The information presented in the SEIS is not intended to be a performance assessment within the meaning of the standards or to demonstrate compliance with the remanded 40 CFR Part 191, Subpart B. Rather, the SEIS describes proposed Test Phase activities that would enable the DOE in the future to ascertain, based on a performance assessment, whether the repository can meet the standards.

Subpart B (40 CFR 191.13) limits cumulative releases of radioactive materials to the "accessible" environment over 10,000 years. This Subpart also limits the annual radiation dose to individual members of the public (40 CFR 191.15) and radioactive contamination of groundwater (40 CFR 191.16) during undisturbed performance of the repository for a period of 1,000 years after disposal of the waste. In essence, the primary objective of Subpart B is to ensure that the disposal system will isolate the waste from the accessible environment by limiting long-term releases and the consequent risks to human individuals. Subpart B, 191.14, also establishes a number of assurance requirements to provide confidence in long-term compliance with the containment requirements (40 CFR 191.14). (See Subsection 10.2.4 for a discussion of 40 CFR Part 191.)

Performance assessment, as defined in 40 CFR 191.12 (q), requires "an analysis that 1) identifies the processes and events that might affect the disposal system; 2) examines the effects of these processes and events on the performance of the disposal system; and 3) estimates the cumulative releases of radionuclides, considering the associated uncertainties, caused by all significant processes and events." For the WIPP project, and consistent with this definition, the final performance assessment method will be a complex process involving seven major components: 1) data collection and model development, 2) scenario development and screening, 3) preliminary consequence analysis, 4) sensitivity and uncertainty analyses, 5) final consequence analysis and comparison with the standard, 6) analysis of undisturbed performance, and 7) documentation.

Data collection regarding the geologic and hydrologic characteristics of the area surrounding the WIPP has been under way for 14 years as part of site characterization and repository design activities (see, for example, Lappin, 1988). Numerical models have been developed that will be incorporated into the performance assessment computational method. Characterization of the disposal system and the surrounding area and the development of models would continue during the Test Phase.

Scenarios describing the possible events that could affect the long-term performance of the repository are being developed. In accordance with Appendix B of 40 CFR Part 191, scenarios can be omitted from the performance assessment if their probability of occurrence is less than 1 chance in 10,000 of occurring over 10,000 years. Some of the events or processes estimated to have a greater probability also may be deleted from the analysis if there is a reasonable expectation that the remaining probability distribution of cumulative releases would not be significantly changed by their

omission. Events retained for the WIPP scenario development include the effects of a pressurized brine occurrence beneath the WIPP, climatic change, groundwater flow, drilling into the repository, and others. It is expected that the scenarios developed to date would be reduced to approximately 10 to 15, which would ultimately be analyzed in the performance assessment.

Preliminary consequence analysis of the scenarios would be used to assemble and test the entire set of codes, models, and techniques that are necessary to project repository performance for comparison with the 40 CFR Part 191 standards. This set of codes, models, and techniques is called the performance assessment methodology. Any deficiencies identified in the methodology would be corrected before the final consequence analysis is performed.

Sensitivity analysis for each scenario would be performed during the preliminary consequence analysis. Sensitivity analysis is a means of determining the relative importance of the parameters used in a calculation. Detailed sensitivity analysis of parameters used in the geologic, hydrologic, and transport components of the performance assessment system would be undertaken, as well as a sensitivity analysis of the repository and shaft components.

Uncertainty analysis determines the uncertainty in the performance assessment calculation resulting from uncertainties in models and the data. Scenario probabilities would be addressed through external peer review. Model uncertainty would be addressed through verification, validations, calibration programs, and quality assurance. Monte Carlo sampling would be used to address uncertainty in input data.

Final consequence analysis would be performed for each scenario that is determined to be significant during the scenario screening process. Calculations would be performed to determine the quantities of radionuclides that could be released to the accessible environment during the first 10,000 years after decommissioning of the WIPP and the probabilities of such releases. This would be performed using the performance assessment methodology described for preliminary consequence analysis and modified as necessary to correct for deficiencies found during the earlier analysis. The results would be compared to the standards in 40 CFR Part 191, Subpart B.

Annual doses for undisturbed performance would be calculated if any release of radionuclides is projected for the first 1,000 years.

The proposed Performance Assessment tests include bin-scale tests and alcove-scale tests to provide data, and to reduce uncertainties in the data, for the performance assessment calculations that would be used for demonstrating compliance with the EPA's long-term disposal standards (40 CFR 191). These tests are also designed to reduce uncertainity in the data regarding compliance with the requirements of RCRA.

- Bin-Scale Tests. The bin-scale tests are being designed to provide information concerning gas production, gas composition, and gas depletion rates as well as radiochemical and hazardous chemical source term data from actual CH TRU waste. The objectives of the bin-scale tests are to:

1) Quantify gas quantities, composition, generation, and depletion rates from TRU waste as a function of waste type, time, and interactions with brines and other repository natural and engineered barrier materials with a high degree of control; the experimental conditions will be primarily representative of the long-term, post-operational phase of the repository and the operational phase

2) Provide a larger-scale confirmation and extension of the laboratory-scale test results, using actual CH TRU waste under repository-relevant, expected conditions

3) Evaluate the synergistic impacts of microbial action, potential saturation, waste compaction, contamination by expected degradation products, etc., on the gas-generation capacity and radiochemical environment of TRU waste

4) Incorporate long-term room closure and waste compaction impacts on gas generation by including supercompacted waste

5) Evaluate effectiveness for minimizing overall gas generation by incorporating getter materials, waste form modifications, and/or engineered alternatives into the CH TRU waste test system

6) Measure solution leachate radiochemistry and hazardous chemical constituent chemistry from saturated TRU waste interactions as a function of many credible environmental variables

7) Determine the amount of volatile organic compounds/hazardous gases released from the TRU waste under realistic repository conditions in order to quantify releases of hazardous constituents and adequately address RCRA requirements.

8) Provide necessary gas-generation and depletion data and source-term information in direct support of WIPP performance assessment analyses, predictive modeling, and related evaluation, and to justify pertinent assumptions used in modeling

9) Help establish an acceptable level of confidence in the performance assessment calculations. Help evaluate pertinent modeling assumptions. Help eliminate most "what if" questions and concerns.

CH TRU waste would be mixed with backfill, brine, and salt to simulate conditions to which the waste would be exposed within the repository. The waste used would be representative of the general TRU waste inventory. The source of the waste would be newly generated waste with high-organic, low-organic, and inorganic processed sludge components. Old waste with high-organic content would also be used. The waste to be used in the bins would be assayed and characterized to identify constituents important to further analysis.

The waste would be tested under a variety of conditions, including aerobic (containing oxygen) and anaerobic (lacking oxygen) conditions that simulate operational and postoperational phases. The waste would be brought into contact with a variety of types and quantities of brines. Experiments would also be conducted to provide information about waste interactions with salt, container metals, backfill, and materials that absorb gases. Finally, experiments would provide information about the production of gas by waste in various modes (including saturation, compaction, bacterial action, and degradation product contamination).

The WIPP bin-scale tests involve testing of specially-packaged and prepared TRU waste in specially designed, transportable sealed bins. The bin would be a metal box with sampling ports and instrumentation. Each bin would be able to accommodate the equivalent of about six drums of CH TRU waste. Each bin would be prepared and filled at the generator facility with TRU waste mixed with backfill and salt. Brine would be added only at the WIPP site. The test bin would fit within a SWB for transportation to the WIPP in a TRUPACT-II.

All test bins would have a carefully sealed internal environment that would be accessed by gas sampling ports, pressure gauges, and control systems, as well as temperature monitors. Some would also have ports for brine injection, liquid sampling, and solids sampling.

See Appendix O and the plan for the Test Phase (DOE, 1989c) for additional details.

- Alcove-Scale Tests. Data would be obtained from the alcove-scale tests on the production, depletion, and composition of gases resulting from in situ degradation of TRU waste. The objectives of the alcove-scale tests are to:

  1) Determine baseline gas composition, generation, and depletion rates for as-received, representative mixtures of TRU waste in a typical, operational phase repository room environment

  2) Determine gas composition, generation and depletion rates for specially prepared mixtures of actual TRU waste (with and without compaction), backfill materials, gas getters, and intruding brine under representative, post-operational phase repository room conditions

  3) Determine the amount of volatile organic compounds/hazardous gases released from the TRU waste under actual repository conditions

  4) Provide an in situ test of gas getter effectiveness and demonstration of waste room backfilling procedures

  5) Confirm alcove-scale estimations of gas generation based on laboratory and bin-scale tests of TRU waste degradation and gas production

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6) Establish an acceptable level of confidence in the performance assessment calculations by validation of modeling assumptions with in situ gas measurements.

These tests would provide additional confidence in the performance assessment analyses described earlier. Because of the potential uncertainties inherent in extrapolating laboratory or even bin-scale results to the full-scale repository, alcove-scale tests would be performed within the WIPP repository to validate gas generation models and predicted impacts for realistic waste inventory emplacements. In addition to eliminating the uncertainties associated with scaling results from smaller-scale experiments, alcove-scale tests would incorporate the impacts of the actual repository environment on the degradation behavior of the waste. The alcove-scale tests would also experimentally address the predicted effect of emplacing engineered backfills on the evolved gases and would examine the gas generating potential of supercompacted waste.

The TRU waste for the alcove-scale tests would include waste both as generated and specially prepared at generator facilities before shipment to the WIPP. Specially prepared CH TRU waste would include backfill and gas getter materials added at the generator facilities, and brine added at the WIPP site. The waste types would be representative of waste proposed to be permanently emplaced in the WIPP, including high-organic, newly generated waste; low-organic, newly generated waste; processed sludges; high-organic old waste; and others.

The alcove-scale tests would be located within six sealed, atmospherically-controlled test rooms or "alcoves." Waste would be located within five alcoves and one alcove would be an empty gas reference-baseline room. An entryway would be fitted with an inflatable packer-seal plug(s) to seal the room and, thus, simulate anoxic repository conditions. Both bin and alcove-scale tests are proposed to obtain gas generation and source term data.

See Appendix O and the Plan for the Test Phase (DOE, 1989c) for additional details.

Integrated Operations Demonstration. The purpose of an Integrated Operations Demonstration would be to show the ability of the waste management system to safely and efficiently certify, package, transport, and emplace waste at the WIPP. Testing and monitoring would be done on generating and storage facility operations, the transportation system, and the WIPP site operations. These testing and monitoring activities are intended to substantiate the safety and efficiency of WIPP operations and associated waste management systems under realistic conditions.

During the Integrated Operations Demonstration, TRU waste would be retrievably emplaced in the repository. The WIPP operating staff would conduct these handling operations in accordance with the requirements of RCRA, other applicable regulations, and Subpart A of 40 CFR Part 191.

The three primary elements of the program would include:

1) Operation of the WIPP with TRU waste at rates of emplacement up to rates that represent full-scale operations of the repository. This would evaluate overall safety and productivity at the WIPP, ensure that operations are consistent with environmental considerations, and demonstrate compliance with regulations and DOE Orders. The interaction and integration of surface, hoist, and underground operations would be evaluated while handling radioactive waste. Further, this evaluation would include the handling of CH waste at operational rates. These waste emplacement operations would be performed concurrently with mining operations.

   Waste management activities to be demonstrated include waste transporter receipt, waste unloading, and waste transfer to the storage locations in the underground disposal area. Activities would be documented and analyzed to develop a safety, productivity, schedule, and operability data base.

2) Waste retrieval, certification and packaging, and loading for shipment to the WIPP by DOE waste generator/storage facilities.

3) Transportation of TRU waste to the WIPP, including shipping container and trailer operations, shipment tracking using the TRANSCOM satellite tracking system, and regulatory compliance monitoring. To ensure that personnel at the WIPP, the defense program facilities, and the contract carrier are prepared to make shipments safely and efficiently, trial runs would be made from defense program facilities to the WIPP (see Appendix D). The purpose of these runs would be to:

   - Demonstrate preparation of TRUPACT-IIs for shipment
   - Meet dispatching requirements
   - Demonstrate that operators at the facilities are prepared for the loading and unloading of TRUPACT-IIs
   - Communicate with drivers and monitor shipment locations using TRANSCOM
   - Establish base transit times from facilities to the WIPP.

During the Test Phase, the need for additional NEPA documentation based on the new information developed would be determined and a document would be prepared, if appropriate. If there were a significant indication of noncompliance, a number of options would be considered (e.g., waste treatment, engineering modifications) for bringing the WIPP into compliance and the required NEPA documentation for those options would be prepared before a decision to proceed was made. In addition, at the conclusion of the Test Phase, another supplement to the EIS would be prepared. At that time it would be determined whether the WIPP would comply with the radiation protection standards issued by the EPA for the disposal of TRU waste (40 CFR Part

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191, Subpart B); compliance with the RCRA Land Disposal Restrictions (40 CFR 268) and other regulatory requirements would be confirmed. If there were a determination of compliance with the EPA standards and other regulatory requirements, and a favorable Record of Decision on the new SEIS, the WIPP would move into the Disposal Phase. If it were determined after considering various options, that the WIPP could not comply with regulatory requirements, the waste would be retrieved and the WIPP would be decommissioned or put to other uses as appropriate.

3.2 ALTERNATIVES

As discussed in Subsection 1.2.1, the 1980 FEIS analyzed a number of alternatives to proceeding with development of the WIPP. These included no action, disposing of TRU waste in the first available high-level radioactive waste repository, and investigating alternative sites. Alternative methods for TRU waste disposal (e.g., transmutation and ejection into space) and alternative geologic media were also explored. The alternatives were compared in tabular form in FEIS Subsection 4.5. The alternatives evaluated in this SEIS are consistent with the phased approach established in the Record of Decision of 1981 and "supplement" those of the 1980 FEIS. Taken together, the FEIS and this SEIS have explored and objectively evaluated all reasonable alternatives for disposal of defense TRU waste generated since 1970.

As discussed in Subsection 3.1, the Proposed Action is the same as the decision rendered in the Record of Decision (DOE, 1981a), along with proposed modifications. Major portions of the Test Phase under the Proposed Action would be initiated in 1990 with the emplacement of selected TRU waste underground. The fundamental decision at this time is whether to initiate the proposed Test Phase by transporting to and emplacing TRU waste in the WIPP; to conduct tests (part of the Test Phase) aboveground and not emplace waste in the WIPP until compliance with the EPA environmental protection standards in 40 CFR Part 191, Subpart B, has been determined on the basis of a performance assessment; or to take no further action regarding the WIPP. The DOE has determined that the use of simulated, nonradioactive waste in support of the performance assessment and proceeding with performance assessment with no tests involving waste are unreasonable alternatives, as explained in Subsection 3.3.

3.2.1 No Action Alternative

Under the No Action Alternative, TRU waste would continue to be generated and stored. No waste would be emplaced in the WIPP underground. Storage of TRU waste would continue, utilizing existing storage features (and, where necessary, improvements, modifications, and enlargements) at the generator/storage facilities, as well as new storage facilities. Treatment of waste containing hazardous constituents subject to RCRA Land Disposal Restrictions in accordance with EPA recommendations may be required. The WIPP would be decommissioned and/or put to other uses as appropriate.

The FEIS and this SEIS have analyzed the environmental consequences of the No Action Alternative under several different assumptions and conditions. In general, it is

estimated that if the DOE would provide effective monitoring and maintenance of storage facilities, adverse health effects for the general public would be quite small, and the principal adverse effects, also small, would be related to occupational activity at the facility. Health effects would continue at such levels for the indefinite future under the hypothesis of DOE control.

Alternatively, if the DOE were not to maintain effective control of storage facilities, it is estimated that intruders could receive substantial radiation doses, a situation that could persist for the indefinite future. Therefore, the No Action Alternative would require effective long-term institutional control to avoid such unwanted consequences.

It is believed to be imprudent and unfair to rely on institutional methods to control long-term hazards such as TRU waste pose. "Imprudent" because, despite the current society's best intentions, there is no way to assure that future societies will have the means and will to provide effective oversight. "Unfair" because long-term institutional control would burden future generations without their consultation or consent, especially if the current society had reasonable alternatives that it could have implemented to avoid the burden. Therefore, sound environmental planning requires aggressive development of an effective, permanent disposal method for TRU waste. This would not be achieved by the No Action Alternative.

In its two rulemakings for waste containing long-lived radionuclides, the EPA has explicitly limited reliance on institutional controls. For disposal of uranium mill tailings, the EPA stated ". . . that protection from the long-term hazards associated with radioactive waste should primarily rely on passive control methods" (48 FR 45936, October 7, 1983). For disposal of high-level and transuranic waste, the EPA required that assessments of compliance with its disposal standards may not consider any contribution from active institutional controls for more than 100 years after disposal (40 CFR 191.14(a)). In both rulemakings, the EPA also urged that institutional controls should be provided for as long as useful or practicable as supplements to adequate physical control methods.

The intent of the U.S. Congress with respect to the WIPP and its mission was defined in Public Law 96-164, the "Department of Energy National Security and Military Applications of Nuclear Energy Authorization Act of 1980." Paragraph (a) of Section 213 states, "Notwithstanding any other provision of law, the Waste Isolation Pilot Plant is authorized as a defense activity of the Department of Energy. . . ." The mission of the project is also described in Paragraph (a) Section 213: the WIPP would have ". . . the express purpose of providing a research and development facility to demonstrate the safe disposal of radioactive wastes resulting from the defense activities and programs of the United States. . . .". The No Action Alternative, thus, is inconsistent with Congressional intent.

Additionally, the No Action Alternative is contrary to the intent of the DOE's "Defense Waste Management Plan" (DOE, 1983) which outlines the Departmental requirements for the permanent disposal of TRU and other radioactive waste generated by DOE activities. The Defense Waste Management Plan states that the objective for defense TRU waste management is ". . . to end interim storage and to achieve permanent disposal."

LIBRARY OF THE UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

3.2.1.1 Overview of Storage Facilities

The facilities constructed after 1970 for TRU waste retrievable storage were designed as safe holding areas until a permanent waste repository was established for final disposal. In 1970, the Atomic Energy Commission adopted a policy requiring that waste containing TRU nuclides producing more than 10 nanocuries of alpha activity per gram be packaged and stored separately from other radioactive waste. The DOE's practice for many years has been to store TRU waste in such a way that it can be readily retrieved in an intact, contamination-free condition for 20 years.

These facilities require regularly scheduled monitoring and maintenance to insure public and worker health and safety. This involves routine environmental monitoring of air, groundwater, soil and/or other parameters to assure continued containment of TRU waste. Equipment and personnel would be required during the lifetimes of these facilities for monitoring, inspection, and maintenance. This is in contrast to the concept of a permanent waste repository. A permanent repository would be subject to comprehensive monitoring during the emplacement or operations phase. Monitoring would be conducted during the 25-year Test and Disposal Phases and a postclosure care period to meet EPA requirements in 40 CFR Part 264, Subpart G and parallel New Mexico regulations. Monitoring would be conducted for a longer period if there were significant concerns to be addressed by further monitoring, in compliance with 40 CFR 191.14(b).

A brief description of DOE retrievable and temporary facilities is useful in understanding the types, characteristics, and capabilities of such facilities. In general, methods for the retrievable storage of TRU waste are similar among DOE generator/storage facilities. Waste stored since 1970 has been packaged in plywood boxes, 55-gal drums or metal boxes and is stacked in layers on asphalt pads. The greatest volume of waste has been covered with plywood and plastic vinyl sheeting, and overlain by approximately 3 ft of earth. This waste is readily retrievable when permanent disposal becomes available. Additionally, some waste is kept in aboveground facilities which include concrete warehouse-type structures, large metal storage containers, or inflatable (i.e., air support) buildings. A description of facilities follows.

At the Hanford Reservation in Washington, TRU waste in solid form has been stored in retrievable storage facilities having a design life of 20 years. Five sites covering a total surface area of 270,000 ft^2 have been used. The containers at these sites are stored in layers on asphalt pads usually covered with plywood and plastic vinyl sheeting, overlain by 4 ft of earth. Through 1988, 37,641 metal drums, 626 metal boxes and 462 miscellaneous containers comprising an estimated 545,000 ft^3 (55,510 alpha Ci) of TRU waste have been stored at Hanford Reservation. Newly generated CH TRU waste through the year 2013 is expected to add an estimated 101,000 ft^3 of waste, which would be retrievably stored in the TRU Storage and Assay Facility. Due to limited space within this facility, additional storage facilities would be needed to contain the projected inventory. The TRU Storage and Assay Facility began operation in 1985 and provides the capabilities to examine and assay newly generated drum waste, perform certification activities, and store waste. A Waste Receiving and Processing Facility is planned to examine and process stored and newly generated TRU waste.

The Rocky Flats Plant Supercompaction and Repackaging Facility and TRU Waste Shredder would process solid waste which is newly generated during routine production operations, maintenance activities, and laboratory support operations. The Colorado Department of Heath currently recognizes seven interim status storage areas at the Rocky Flats Plant for TRU mixed waste. The areas differ in size for a total permitted storage capacity of 1,601 yd^3. The storage units are within existing structures having concrete floors covered with epoxy paint and fenced areas within the buildings, which allow segregation of the storage facility from adjacent operations.

Two categories of waste would be processed: soft or combustible waste, and hard or noncombustile waste. The waste types are seperated into designated drums at the point of generation, and seperation is maintained throughout the waste management operations.

Hard waste packaged in 35-gal steel drums would be directly supercompacted (drum and all) into "pucks", and the pucks would be loaded into 55-gal steel drums for final disposal. Bags of soft waste, initially packaged in 55-gal drums, would be unpacked and precompacted into 35-gal drums, and then the 35-gal drums would be supercompacted as described above.

The Rocky Flats Plant TRU Waste Shredder would be used to process discarded graphite molds and filters. Molds and filters would be shredded for volume reduction and packaged in 35-gal steel drums for supercompaction as hard waste.

A large percentage of the pad-stored defense TRU waste within the DOE complex is located at the Radioactive Waste Management Complex of the Idaho National Engineering Laboratory. CH TRU waste received at the Radioactive Waste Management Complex has been stored at this 56-acre Transuranic Storage Area, a controlled area surrounded by a security fence with an intrusion alarm system. The waste is stored on asphalt pads, each approximately 150 by 700 ft. Solid TRU waste is contained in 4 ft by 7 ft plywood boxes covered with fiberglass reinforced polyester, 55-gal steel drums with polyethylene liners, and steel bins. The containers are intended to be retrievable and free of contamination for at least 20 years. The steel drums are stacked vertically in layers with 1/2 inch plywood separating each layer. When a stack has reached a height of 16 ft, a cover consisting of 5/8 inch plywood, nylon-reinforced polyvinyl sheeting, and 3 ft of earth is emplaced. In addition to the earth-covered waste on asphalt pads at the Idaho National Engineering Lab, there are two operational air support buildings. Presently about 31,000 drums and 1,600 boxes of waste are stored in these two buildings. The remaining storage capacity within these buildings is limited. To date, approximately 1,074,000 ft^3 of retrievably stored TRU waste has been stored at the Idaho National Engineering Laboratory.

The Savannah River Site began storing TRU waste in retrievable form on concrete pads in the early 1970s. As of December 1987, the Savannah River Site had about 368,000 ft^3 of solid post-1970 TRU waste in its Burial Ground. Additionally, the Savannah River Site produces approximately 40,000 ft^3 of newly generated TRU waste annually. TRU waste is in retrievable storage facilities on concrete pads or in shallow trenches. It is contained in concrete and steel boxes, concrete culverts, and galvanized steel drums which are covered with approximately 4 ft of earth or tornado netting (started in 1985).

By 1995, waste in retrievable storage at the Savannah River Site would begin to exceed the 20-year facility design limit.

Since 1971, TRU waste at the Los Alamos National Laboratory has been packaged primarily in steel drums and in fiberglass-coated boxes, with the remaining waste packaged in corrugated metal pipes and concrete culverts. The drums have been coated with a corrosion inhibiter. Packages have been stacked on asphalt pads, then covered with a wooden frame and plastic cover, and finally covered by approximately 3 ft of earth. The waste is densely stacked in modules about 5 drums high and 20 drums wide. Currently, about 259,100 ft^3 of TRU waste is stored, most of it on four asphalt pads. Analysis of waste drums which were retrieved after about 10 years of storage suggests that the drums would probably remain intact for another 10 to 20 years, but would then require repackaging and overpacking.

Since implementation of the TRU Waste Certification Plan in 1987, waste at Los Alamos National Laboratory is stored in a reinforced vinyl fabric covered, aluminum I-beam frame structure erected over an asphalt pad. With regular maintenance, the fabric is expected to last about 20 years. Currently, approximately 11,300 ft^3 of precertified TRU waste have been stored in the fabric covered facility.

The Lawrence Livermore National Laboratory currently temporarily stores CH TRU waste in a 125 ft x 50 ft metal building. The storage capacity is approximately 200 55-gallon drums (i.e., approximately 1,400 ft^3). This facility is a temporary storage and staging area for CH TRU waste prior to shipment to the Nevada Test Site. Existing facilities could store waste generated onsite for approximately two years. Additional facilities would be required for onsite storage of waste generated beyond this two year period. Lawrence Livermore National Laboratory does not currently generate or store RH TRU waste.

The Argonne National Laboratory-East's temporary storage facilities are designed only for staging and temporary storage of TRU waste prior to shipment to other DOE facilities for retrievable storage. The existing temporary storage facility for RH TRU waste consists of six underground storage vaults located in an outdoor limited access area, referred to as the "317" area. These storage vaults have the capacity to temporarily store the equivalent of 180 55-gallon drums (i.e., approximately 1,270 ft^3). Space availability is only one of the limiting factors for storage of RH TRU waste. Criticality controls and exposure risks are also considered in determining a safe quantity of waste that may be temporarily stored at the facility. The criticality limit for fissile material located in this area is 2,000 grams. As of August 1989, Argonne-East had 60 30-gal drums of RH TRU waste (i.e., approximately 240 ft^3). This waste contains approximately 950 grams of fissile material which is approximately half of the allowable limit. The underground storage vaults will need to be replaced with aboveground vaults in the next 5 to 8 years.

CH TRU waste is also currently stored in the "317" area. It is temporarily stored in aboveground metal bins having a storage capacity of eight 55-gal drums per bin. Approximately 750 ft^3 of CH TRU waste is currently in temporary storage at this location. Without offsite shipment of newly generated waste, Argonne National Laboratory-East would require additional temporary storage facilities in approximately 1 to 2 years.

The current volume of CH TRU waste at the Mound Laboratory is approximately 8,500 ft^3 temporarily stored in two primary staging areas, a metal storage building and a concrete block structure. No underground storage of CH TRU waste exists since all previously stored waste has been shipped to retrievable storage at the Idaho National Engineering Laboratory. At the current generation rate of 1,000-2,000 ft^3 per year and without offsite shipment of newly generated waste, additional storage capacity would be required at the Mound Laboratory within 1 to 2 years.

The Nevada Test Site is a retrievable storage facility for CH TRU waste from the Lawrence Livermore National Laboratory. The Nevada Test Site does not generate TRU waste or currently receive TRU waste for storage from any other DOE facility. At the Nevada Test Site, TRU waste is currently stored at the Waste Storage Cell, a portion of the Area 5 Radioactive Waste Management Site. The Waste Storage Cell was constructed in 1988 and consists of a curbed, two-acre concrete and asphalt pad. The pad is constructed with an impermeable liner. TRU waste is packaged in metal DOT Type A boxes and drums and stored in 8 x 8 x 20 foot metal, surplus sea-going cargo carriers located on the pad. The maximum total storage capacity of this facility is 210 cargo carriers (approximately 110,000 ft^3). Fifty cargo carriers (i.e., approximately 22,000 ft^3 of waste) are currently stored at the WSC.

Since 1970, the Oak Ridge National Laboratory-generated CH TRU and RH TRU waste has been retrievably stored primarily at the Oak Ridge National Laboratory Solid Waste Storage Area 5. Storage facilities include two belowground storage buildings for CH TRU waste and three retrievable storage units, including stainless steel lined wells, tanks, and a concrete cask storage building for RH TRU waste. Approximately 20,000 ft^3 of CH TRU waste and 45,000 ft^3 of RH TRU are currently in retrievable storage. At current rates of generation, additional retrievable storage capacity would be required by the mid-1990s. To comply with the requirements of the RCRA, a new aboveground storage facility is planned to replace the belowground storage of CH TRU mixed waste.

3.2.1.2 Requirements Associated with Continued Use of Storage Facilities

The continued use of existing DOE retrievable storage facilities beyond the design life and the continued accumulation of newly generated waste at these sites would require: 1) continued or expanded monitoring programs, 2) routine retrieval and re-emplacement of TRU waste from retrievable storage facilities, 3) modifications of existing storage arrangements to increase useful life, 4) construction of new facilities for treatment and/or storage of additional waste, and 5) possible modifications to RCRA permits. Each of these requirements is addressed more fully below.

Monitoring Programs. The DOE maintains an ongoing environmental surveillance program of stored TRU (and other radioactive) waste as required by draft DOE Orders 5400.3 ("Radiation Protection of the Public and the Environment," 1988) and 5484.1 ("Environmental Protection, Safety, and Health Protection Information Reporting Requirements," February 1981b). Such surveillance programs would continue for the foreseeable future and probably be expanded to meet the requirements of increased TRU waste volumes in retrievable storage.

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Routine monitoring for radioactive materials and chemical substances on DOE facilities and in the surrounding areas is used to document compliance with applicable standards, identify undesirable trends, provide information for the public, and contribute to general environmental knowledge. Thus, this information is used to assure continued protection of the environment, and safety and health of workers and the general public. If an undesirable trend is discovered from routine surveillance, detailed environmental studies are conducted to determine the extent of the problem and to provide the basis for specific remedial actions. Information obtained from environmental monitoring complements data on specific releases.

The comprehensive monitoring program at the Idaho National Engineering Laboratory, where a large proportion of the current TRU waste in inventory is stored, is representative of such programs at the nine other facilities. Under the No Action Alternative, the following specific types of environmental monitoring would have to be continued and potentially expanded at the Idaho National Engineering Laboratory: 1) radiation surveys of the ground surface to ensure that the general area of the storage facilities would not present a radiological hazard, 2) soil sampling tests designed to detect plutonium (and other radionuclides) at the surface and to depths of 6 and 12 inches, and 3) studies of the potential for horizontal migration of contaminants near the ground surface and for vertical migration below the surface.

Other ongoing surveillance at the Idaho National Engineering Laboratory includes the following. Air monitors are presently installed around the perimeter of the waste management complex to determine the airborne concentration of radionuclides. The lack of surface water restricts water sampling activities to runoff and snowmelt. Food crops grown offsite are monitored to determine the uptake of radioisotopes from soils. Soil samples are collected from burrows of small animals and are analyzed for the presence of radionuclides. Wells located around the periphery of the waste management complex are used to sample the aquifer at depths of approximately 600 ft below the ground surface.

Finally, environmental parameters are monitored within portions of the waste management pads themselves. Dew point and temperature measuring probes have been placed at various depths inside the arrays of waste containers because these parameters affect corrosion rates. Metal strips are also placed throughout the stacked waste to monitor corrosion levels indicative of the deterioration of metal waste containers.

Retrieval and Repacking. Moisture, temperature, and chemical parameters combine within the TRU waste storage environment to cause the gradual corrosion of metal containers within which much of the TRU waste is packaged. Variations in these parameters at different DOE storage facilities either increases or decreases the rate at which containers of TRU waste corrode and deteriorate. As containers age and deteriorate, container failure or breach becomes more likely, with the potential for contamination of the environment and increased risk to workers and the public.

Corrosion studies performed on nonradioactive test drums by the Savannah River Site show complete penetration of the galvanized outer coating in localized areas on 55-gal test drums exposed to moisture after 4.5 years of storage. Penetration into the carbon

steel also had begun in these localized areas on the drum. These results do not indicate breach of drums within this short time period, but do indicate the increasing potential for container failure and resultant environmental contamination from similarly stored TRU waste drums as the period of storage increases. Additionally, limited sampling of drums removed from storage cells at the Idaho National Engineering Laboratory after 12 years revealed that container integrity remained intact, although exterior corrosion had begun.

To avoid the potential breach of drums and resultant environmental contamination, a routine program of retrieving drums and repackaging or overpacking (placing into a larger container) TRU waste on a cyclical basis would be required. Subsequently, drums would be returned to retrievable storage. The period of storage before containers would be retrieved and repackaged is estimated to be approximately 20 years, but is dependent upon the specific storage environment and package types at individual storage facilities. Monitoring and inspection of waste drums during the intervening 20 years would continue.

As long as active institutional control is effective at DOE retrievable storage facilities, monitoring and surveillance would detect movement of radionuclides or chemicals. Appropriate corrective measures would be taken, and there would be no expected long-term impacts to the offsite populations.

See Appendix P for additional discussion.

Modification of Existing Facilities and Practices. A variety of modifications would eventually be needed to manage TRU waste now in retrievable storage. In order to extend the useful life of existing TRU waste drums, such containers could be removed from some storage structures and a corrosion-inhibiting preservative could be applied over the metal. The containers would then be replaced in storage. This method of extending packaging life would be most appropriate at DOE facilities where stacked waste drums are readily accessible because they are housed in controlled facilities and not currently covered by several feet of earth. Such techniques could be employed for some waste at the Idaho National Engineering Laboratory, Los Alamos National Laboratory, and possibly other facilities. Plywood boxes covered with fiberglass-reinforced polyester, which have often been found to be damaged by heavy earth cover, wood rot, retrieval, or handling, would require more extensive processing/repackaging prior to being returned to storage.

Another possible modification would be in-place improved confinement to protect waste stored in metal containers against penetration by water and plant root systems or animal intrusion. This may prolong the integrity of storage containers and thus reduce the potential for waste migration hazard. In this modification, an additional cover of approximately 10 ft of compacted clay, plus an approximate 3-ft cover of riprap material could be built over existing mounds of waste that is currently stored on asphalt pads and covered by earth. Tightly compacted clay would inhibit water penetration. The earthen cover would be sloped to provide drainage, and the riprap would serve as an erosion deterrent.

In conjunction with the previous modifications, pressure grout sealing of the sediments beneath the asphalt or concrete pads upon which waste is placed could minimize potential downward migration of any radionuclides or chemicals as long as the grout remained intact. Such pressure grouting is accomplished by pumping a chemical grout into trenches or drilled openings below and surrounding the waste drums. This would be done before the placement of the clay and riprap cover.

DOE facilities storing mixed waste may be required to modify or construct facilities to comply with the requirements of RCRA. RCRA requirements for managing mixed waste include provisions for routine inspections of containers, labeling, and storage in a manner that ensures container integrity. Such requirements could require segregating TRU waste which is co-contaminated with hazardous chemical constituents. The co-contaminated proportion includes approximately 60 percent of the waste proposed for disposal in the WIPP.

Additionally, storage structures for newly generated mixed waste would need to be constructed to meet RCRA requirements. It is estimated that storage of mixed waste could require at least four times the space needed for the present methods of storage; storage would be only in aboveground structures.

Further, some of the hazardous waste constituents of waste proposed for shipment to the WIPP would be subject to the land disposal restrictions of RCRA if the no-migration variance for the WIPP is not granted. Absent treatment of the waste in accordance with EPA treatment standards, the storage of such waste is prohibited unless such storage is solely for the purpose of accumulating such quantities of waste as is necessary to facilitate proper treatment. DOE retrievable storage facilities having waste subject to the Land Disposal Restrictions would need to treat the waste in accordance with the EPA treatment standards.

In addition to new construction and possible treatment of waste required to meet the RCRA requirements, several DOE retrievable storage facilities may require additional features to store newly generated TRU waste. As discussed above, an additional 3,848,600 ft^3 of CH TRU and 44,600 ft^3 of RH TRU would be generated by DOE facilities prior to the year 2013. This would approximately triple the existing TRU waste storage requirements. Such new facilities would be aboveground structures which would meet the RCRA and DOE requirements. The storage facilities, under one concept, would probably resemble large warehouses designed to protect the processed waste for the next 20 or more years until a permanent repository could be developed. The buildings would be constructed of precast concrete panels which are exceptionally strong and relatively reasonable in cost. These panels would contain high-tensile steel reinforcement, and would be transported to the construction site after being properly aged. Ventilation would be introduced into the building through a high efficiency particulate air (HEPA) filter system and exhausted through a second system of HEPA filters; air filtration systems would be equipped with fire protection.

Waste containers would be delivered to the storage facility and stacked on end, several high, with plywood sheets between layers. Conventional material handling equipment would be used to stack drums. The buildings would be designed to withstand snow loading, tornados, or other natural events which could impact the facility and its

contents. Security measures would be required to protect the waste from vandalism and access by unauthorized persons.

The DOE is currently evaluating options for the storage of TRU waste. Such options for the next three years include other DOE storage facilities. Options for longer-term storage include Department of Defense facilities and potential commercial facilities as well as DOE facilities. Appropriate NEPA documentation would be prepared as part of this process.

3.2.2 Alternative Action

This SEIS also evaluates an alternative to the Proposed Action under which only those tests that can be performed without emplacing waste underground would be conducted until it is determined that the WIPP complies with the EPA standards and other regulatory requirements for the long-term protection of the environment from the disposal of TRU waste. Of those components of the Test Phase that are proposed for the WIPP underground, only the bin-scale test portion could be reasonably conducted at a location other than the WIPP underground.

Thus, this alternative is essentially the same as the Proposed Action except for changes in the Test Phase. The bin-scale tests would be conducted at a DOE location other than the WIPP underground. These tests would need to be conducted in a specially engineered aboveground facility that would be constructed for this purpose. This alternative calls for no radioactive waste emplacement into the WIPP underground until the bin-scale tests performed at an alternative location have been completed, and the results used in a performance assessment for determining compliance with 40 CFR Part 191, Subpart B.

Because the alcove-scale tests could not be practically or usefully performed anywhere other than the WIPP underground, the results of the alcove-scale tests would not be available to allow confident extrapolation of laboratory and bin-scale results to a full-scale representative repository loading. (Alcove-scale tests must be conducted underground in order to provide "real-world" data, with the fewest simulations or restraints that could potentially bias the end results of any of the test programs. Only the alcove-scale tests would incorporate the environmental, possibly synergistic effects of the repository itself (i.e., gases and fluids released from the host rock salt, salt mine geochemistry and chemistry, etc.) on waste degradation rates and modes. Thus, the uncertainty in the performance assessment under the Alternative Action would be greater than under the Proposed Action. If the uncertainty in the performance assessment should be unacceptable, the DOE would evaluate further courses of action. One option might be to conduct alcove-scale tests similar to those described in the Proposed Action. In that case, such alcove-scale tests would be delayed for up to 5 years longer than the Proposed Action (2 years for bin-scale facility construction and 3 years for bin-scale testing and performance assessment evaluation).

In addition, the Integrated Operations Demonstration portion of the WIPP Test Phase would not be conducted prior to the completion of the compliance determination. This is in keeping with the concept of not bringing waste into the WIPP during this period.

The objectives of the bin-scale tests under this alternative are identical to those described under the Proposed Action. Bin-scale tests for this alternative could be accomplished at any one of several DOE facility locations and would require the construction of a specialized facility to perform the tests. Possible alternative locations include the Idaho National Engineering Laboratory, the Rocky Flats Plant, the Nevada Test Site, and the WIPP aboveground. For purposes of analyzing the impacts of this alternative, the Idaho National Engineering Laboratory was chosen as a representative site. It is not the DOE's intent to propose the Idaho National Engineering Laboratory as the site for bin-scale tests, but simply to use it to illustrate representative levels of impact. As is demonstrated in the impact section for this alternative (Subsection 5.3), the impacts associated with facility construction and the conduct of bin-scale tests at the Idaho National Engineering Laboratory would be equivalent to the impacts from construction and conduct of bin-scale tests at other locations. This is because of the localized and temporary nature of construction impacts and the small scale of the TRU waste bin-scale tests. Impacts associated with waste transportation could vary, depending on the site chosen, but would be small.

Under this alternative, a controlled-environment facility would be built aboveground. The actual building would be tornado and earthquake resistant. It would be required to have a minimum 12-ft interior clear height and would have a floor space of 60 ft by 110 ft. An air lock entryway, bin unloading and preparation area, bin storage area, office, laboratory, and forklift holding area would be included in the interior space. The instrumented facility would have fire detection and suppression systems, and a heating, ventilation, and air conditioning (HVAC) system with double HEPA filters. Test equipment would include radiation monitoring equipment, chemical and gas analysis equipment, a data acquisition system, and other items. A 5-ton-capacity overhead crane and a 3-ton forklift truck would be required for handling.

The estimated total cost for design, site preparation, and construction would be approximately $3.5 million in 1989 dollars. It should be noted that costs would be duplicative because a test facility is already in place in the WIPP underground. The time required for RCRA permitting and the design and construction of such a facility is estimated to be approximately 2 years. In effect, the start of bin-scale testing would be delayed for at least a 2-year period pending the securing of permits, completion of engineering designs, and construction.

3.3 ALTERNATIVES NOT CONSIDERED IN DETAIL

The DOE also considered the possibility of performing experiments in support of the performance assessment with simulated, nonradioactive waste. While this alternative holds the potential to avoid any effects associated with the use of radioactive waste during the Test Phase, it was determined to be unreasonable.

For the confident evaluation of the effect of gases on the long-term behavior of the repository, it is necessary to use actual TRU (radioactive) waste. Several different types of data regarding the behavior of TRU waste are required. These include information about gas generation, gas specification, and gas depletion rates as a function of time and of various waste conditions. The impacts of radiolytic, bacterial, and chemical

corrosion degradation mechanisms can be adequately analyzed only in tests that use actual TRU waste. Finally, the synergisms, or complex interactions, between various ongoing in situ processes can be effectively analyzed only when actual TRU waste is used.

A variation of this alternative would be to proceed with the performance assessment with no tests using waste in the WIPP and no new construction for aboveground tests. This alternative is unreasonable for the reasons given above with respect to using simulated waste. In both cases, the DOE would not have sufficient confidence in the quality of the data to be used in conducting a performance assessment that would provide a basis for determining compliance with 40 CFR Part 191, Subpart B.

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UNIV. OF ILL. URBANA-CHAMPAIGN

4.0 DESCRIPTION OF THE EXISTING ENVIRONMENT AT THE WIPP SITE

This section describes the existing environment at the WIPP site and summarizes and updates the information provided in Section 7 and the referenced appendixes of the FEIS. Information that describes the existing environment at the 10 DOE facilities that may eventually transport post-1970 TRU waste to the WIPP is available in several DOE reports (1988a, 1988b, 1988c, 1987, 1984, 1982, 1980a, 1980b, 1979a, 1979b).

4.1 EXISTING ENVIRONMENT

The monitoring of construction activities, the continuation of studies initiated for the FEIS, and the initiation of studies since the FEIS have generated new information concerning the WIPP site. This section summarizes and updates FEIS Section 7.1; it also includes the results of the environmental monitoring programs and raptor (bird of prey) studies initiated since the FEIS.

4.1.1 Biological Environment

The WIPP site is in an area characterized by stabilized sand dunes. The vegetation is dominated by shinnery oak (*Quercus havardii*), mesquite (*Prosopis glandulosa*), sand sage (*Artemisia filifolia*), dune yucca (*Yucca campestris*), smallhead snakeweed (*Gutierrezia microcephala*), three-awn (*Aristida* spp.), and numerous species of forbs and perennial grasses. The dominant shrubs are deep-rooted species with extensive root systems. The shrubs not only stabilize the dune sand but serve as food, shelter, and nesting sites for many species of wildlife inhabiting the area.

The wildlife is characterized by numerous species of mammals, birds, reptiles, and amphibians. The most conspicuous mammals at the site are the black-tailed jack rabbit (*Lepus californicus*) and the desert cottontail (*Sylvilagus auduboni*). Common small mammals found at the WIPP site include Ord's kangaroo rat (*Dipodomys ordii*), the plains pocket mouse (*Perognathus flavescens*), and the northern grasshopper mouse (*Onychomys leucogaster*). Big-game species, such as the mule deer (*Odocoileus hemionus*) and the pronghorn antelope (*Antilocapra americana*), and carnivores, such as the coyote (*Canis latrans*), are present in small numbers.

Numerous birds inhabit the area either as transients or year-long residents. Loggerhead shrikes (*Lanius ludovicianus*), pyrrhuloxias (*Cardinalis sinuata*), and black-throated sparrows (*Amphispiza bilineata*) are examples of common residents. Migrating or breeding waterfowl species do not frequently occur in the area. Some raptors [e.g., Harris hawks (*Parabuteo unicinctus*)] are residents. The density of large-avian-predator nests has been documented as among the highest recorded in the scientific literature. Aquatic habitats near the WIPP site include stock-watering ponds and tanks. These may be frequented by yellow mud turtles (*Kinosternon flarescens*), tiger salamanders

(*Ambystoma tigrinum*), and occasional frogs and toads. Fish are sometimes stocked in the ponds and tanks.

The DOE consulted with the U.S. Fish and Wildlife Service (USFWS) in 1979 to determine the presence of threatened and endangered species at the WIPP site (see Appendix I of the FEIS). At that time, the USFWS listed the Lee pincushion cactus (*Coryphantha sneedi* var. *leei*), the black-footed ferret (*Mustela nigripes*), the American peregrine falcon (*Falco peregrinus anatum*), the bald eagle (*Haliaeetus leucocephalus*), and the Pecos gambusia (*Notropis simus pecosensis*) as threatened or endangered and as occurring or having the potential to occur on lands within or outlying the WIPP site. In 1989, the DOE again consulted with the USFWS to update the list of threatened or endangered species that occur or could occur on lands within or outlying the WIPP site. The USFWS advised the DOE that the list of species provided in 1979 is still valid except that the black-footed ferret (*Mustela nigripes*) should now be deleted (USFWS, 1989). The DOE believes that the actions described in the SEIS will have no impact on any threatened or endangered species because these activities do not involve any ground disturbance that was not already evaluated in the FEIS. In addition, there is no critical habitat for terrestrial species identified as endangered by either the USFWS or the NMDG&F at the site area.

Also in 1989, the DOE consulted with the New Mexico Department of Game and Fish (NMDG&F) regarding the state-listed endangered species in the vicinity of the WIPP site. The NMDG&F currently lists (based on NMDG&F Regulation 657, dated January 9, 1988) seven birds and one reptile that are in one of two endangerment categories and that occur or are likely to occur at the site. The NMDG&F agreed that the proposed WIPP activities would probably not have appreciable impacts on state-listed endangered species in the area (NMDG&F, 1989). The Handbook of Rare and Endemic Plants of New Mexico (UNM, 1983), which lists the plants in New Mexico classified as threatened, endangered, or sensitive, includes 20 species, representing 14 families, that are found in Eddy County and could occur at or near the WIPP site.

For a detailed description of the biological environment of the area, the reader is referred to Subsection 7.1 and Subsection H-5 of Appendix H in the FEIS, the literature cited therein, and the WIPP Ecological Monitoring Program described in SEIS Subsection 2.9.2 (Reith and Daer, 1985; Fischer et al., 1985, 1987, 1988).

4.1.2 Socioeconomic Environment

The socioeconomic environment of the area surrounding the WIPP site is described in Subsection 7.2 of the FEIS. Since the publication of the FEIS, declines in the oil, gas, and mining industries have depressed the economy of the area.

There are 26 permanent residents within 10 miles of the WIPP site. Most of the population within 50 miles of the WIPP site is concentrated in and around the communities of Carlsbad, Hobbs, Eunice, Loving, Jal, and Artesia, New Mexico. The nearest community is the town of Loving, New Mexico, 18 miles west-southwest of the site center. The population of Loving decreased from an estimated 1,600 in 1980 to 1,450 in 1986, the year of the latest census. The nearest population center is the city of Carlsbad, New Mexico, 26 miles west of the site. The population of Carlsbad has

increased from an estimated 28,600 in 1980 to an estimated 29,500 in 1988. The transient population within 10 miles of the site is associated with ranching, maintenance of oil and gas wells, and potash mining. There are three ranches within 5 miles of the site; these are the Mills, Smith, and Mobley ranches. Only the Mills Ranch, owned by J. C. Mills, has a ranch house located within five miles of the site. Three mining operations within 10 miles of the WIPP site employ approximately 360 persons per shift, with 450 persons present during shift changes.

4.1.3 Transportation

The WIPP site can be reached by rail or highway. The DOE has constructed a rail spur to the site from the Atchison, Topeka and Santa Fe Railroad (ATSF) six miles west of the site (see Figure 2.1). The site can be reached from the north and south access roads constructed for the WIPP project. The north access road intersects U.S. Highway 62/180 (U.S. 62/180) 13 miles north of the WIPP site. The south access road intersects New Mexico Highway 128 (NM 128) four miles to the southwest.

4.1.4 Land Use

The land use surrounding the WIPP site has not changed since the preparation of Subsections 7.2.2, 8.1, and Section 12 of the FEIS, with the exception of land-use restrictions imposed for the WIPP project. Control Zone IV, containing approximately 11,000 acres, has been released for unrestricted use. This allows exploration for, and development of, mineral resources (oil, gas, sylvite, etc.) and permanent habitation, which were previously restricted.

The WIPP site consists of 16 sections (10,240 acres) of Federal land in Township 22 South, Range 31 East. Except for one section designated the DOE Exclusive Use Area, surface land use has remained largely unchanged during WIPP construction activities. Cattle ranching is the major land use within 10 miles of the DOE Exclusive Use Area. Mining and drilling for purposes other than support of the WIPP project are restricted within the 16-section WIPP site.

4.1.5 Air Quality

Selected air pollutants have been measured at the WIPP site since 1976 and were reported in Subsection 7.1.1 of the FEIS. Since the preparation of Subsection 7.1.1 of the FEIS, a more extensive air-quality monitoring program has been established. Seven classes of atmospheric gases regulated by the EPA have been monitored at the WIPP site since August 27, 1986. These gases are carbon monoxide (CO), hydrogen sulfide (H_2S), ozone (O_3), oxides of nitrogen (NO, NO_2, NO_x), and sulfur dioxide (SO_2). Total suspended particulates (TSP) are monitored in conjunction with the air-monitoring programs of the Regulatory and Environmental Surveillance Programs. The results of the monitoring program are detailed in the annual reports for the Environmental Monitoring Program (Fischer et al., 1987; 1988) which indicate that air quality in the area of the WIPP site usually meets State and Federal standards. However, the TSP standards are occasionally exceeded during periods of high wind and blowing sands. Also, the ambient-air-quality standard for sulfur dioxide has been infrequently exceeded. During two periods in April and May, 1987, measured sulfur dioxide levels at the WIPP

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site exceeded New Mexico's air quality standards. There were no unusual WIPP activities during these periods that would account for these elevated levels and, as these were isolated incidents, tracing their sources was impossible.

4.1.6 Cultural Resources

As reported in Subsection 7.2.1 and Appendix H (Subsection H.1) of the FEIS, the area of the WIPP site was used by nomadic aboriginal inhabitants who left little evidence of their earlier activities. Since the publication of the FEIS, two archaeological investigations have been performed. These investigations, performed by Lord and Reynolds (1985) and Mariah Associates (1987), provide further insight into the life of the hunter-gatherers who occupied the area of the WIPP site. The 1985 investigation excavated three sites identified in the FEIS that were in areas that could have been disturbed during construction activities. These three sites were two plant-collecting and processing sites and one base camp used between 1000 B.C. and A.D. 1400. The artifacts recovered from the excavations have been placed in the Laboratory of Anthropology at the Museum of New Mexico in Santa Fe.

The 1987 investigation covered Control Zones III and IV and areas identified for possible land exchange. Sites encountered in this investigation tended to lack evident or intact features. Definable features were limited to concentrations of lithic material and other evidence of human habitation and use. No definite structures were identified. Of the 40 new sites defined, 14 were considered eligible for inclusion in the National Register of Historic Places (NRHP). Twenty-four sites were identified as having insufficient data to determine eligibility, and two sites were determined to be ineligible for inclusion in the NRHP. The eligible and potentially eligible sites have been mapped and are being avoided by the DOE in its current activities at the WIPP site.

4.1.7 Background Radiation

The background radiation conditions in the vicinity of the WIPP site are influenced by natural sources of radiation, fallout from nuclear tests, and one local research project (Project Gnome). Prior to the WIPP project, long-term radiological monitoring programs were established in southeastern New Mexico to determine the widespread impacts of nuclear tests at the Nevada Test Site and to evaluate the effects of Project Gnome. Project Gnome, which was a part of the Plowshares for Peace program, resulted in the underground detonation of a nuclear device on December 10, 1961, at a site 7.5 miles southwest of the WIPP site. The results of these monitoring programs are summarized in "Compilation of Historical Radiological Data Collected in the Vicinity of the WIPP Site" (Bradshaw and Louderbough, 1987). In addition, background radiation levels have been measured at the WIPP site since 1976 and were discussed in Appendix H of the FEIS.

The WIPP Radiological Baseline Program (RBP) was initiated in July 1985 to describe background levels of radiation and radionuclides in the WIPP environment prior to the underground emplacement of radioactive waste. The RBP consists of five sub-programs: 1) atmospheric baseline; 2) ambient radiation (measuring gamma radiation); 3) terrestrial baseline (sampling soils); 4) hydrologic baseline (sampling surface water and bottom sediments and groundwater); and 5) biotic baseline (analyzing radiological

parameters in key organisms along potential radionuclide-migration pathways). The monitoring program is described by Reith and Daer (1985).

Mean gross alpha activity in airborne particulates has shown little variation and is within the range of 1 to 3 x 10^{-15} microcuries per milliliter (μCi/ml). Mean gross beta activity in airborne particulates fluctuates but is typically within the range of 1 to 4 x 10^{-15} and 1 to 4 x 10^{-14} μCi/ml. A peak of 3.5 x 10^{-13} μCi/ml in the mean gross beta activity occurred in May 1986 and has been attributed to the Chernobyl accident in the Soviet Union. The average level of gamma radiation in the environment is approximately 7.5 microrentgen per hour (μR/hr), or approximately 66 mrem/yr. On the average, a person in the United States receives an effective dose equivalent of 200 mrem/yr from all sources of radiation. Radionuclide concentrations in soil, surface water, sediment samples, and key organisms fall within expected ranges and do not indicate any unexpected environmental concentrations. Detailed results of the RBP are provided in Banz et al. (1987) and Flynn et al. (1988).

4.2 GEOLOGY

4.2.1 Regional Geology

This subsection briefly discusses the regional geology within 200 miles of the WIPP site. A more detailed discussion of the regional geology is presented in Subsection 7.3 of the FEIS (DOE, 1980a) and in the Geological Characterization Report (Powers et al., 1978).

The geologic history of the region, summarized in Figure 4.1, can be subdivided into three phases following the formation of the crystalline basement complex (Precambrian rocks), 1 to 1.5 billion years before the present. During the first phase, lasting until about 600 million years before the present (i.e., the beginning of the Paleozoic Era), Precambrian rocks were uplifted and eroded, forming a near-level plain within the region. The second phase, corresponding to the Paleozoic Era (lasting until approximately 230 million years before the present), was a period of almost continuous marine submergence with accumulations of continental-shelf and marine-basin deposits. By early Permian time, tectonic activity (i.e., structural deformation) that apparently occurred during Mississippian and Pennsylvanian time ceased, and basin subsidence increased. Reefs developed during mid-Permian time; eventually the Permian sea became more saline (brine), and consequently, brine-related minerals precipitated from the brine to form the thick evaporite deposits of the Castile, Salado, and Rustler Formations.

The third phase, from Permian to present, has experienced mainly continental environments and relatively stable tectonic conditions. Subsurface dissolution of the Permian evaporites probably began during this phase or possibly as early as the late Permian. Also during this third phase, periods of continental deposition alternated with erosional episodes and tilting of the sedimentary units. Unconformities caused by this tilting represent intervals during which the salt beds were tilted and subjected to downslope movement, deformation, and probable dissolution.

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ERA	PERIOD	EPOCH	YEARS* DURATION	YEARS* BEFORE THE PRESENT	MAJOR GEOLOGIC EVENTS–SOUTHEAST NEW MEXICO REGION
CENOZOIC	Quaternary	Holocene	10,000		Eolian and erosional/solution activity. Development of present landscape.
		Pleistocene	1,800,000	1,800,000	
	Tertiary	Pliocene	3,400,000		Deposition of Ogallala fan sediments. Formation of caliche caprock.
		Miocene	18,800,000		Regional uplift and east-southeastward tilting; Basin-Range uplift of Sacramento and Guadalupe-Delaware Mountains.
		Oligocene	13,000,000		
		Eocene	16,500,000		Erosion dominant. No Early to Mid-Tertiary rocks present.
		Paleocene	11,500,000	65,000,000	Laramide "revolution." Uplift of Rocky Mountains. Mild tectonism and igneous activity to west and north.
MESOZOIC	Cretaceous		70,000,000		Submergence. Intermittent shallow seas. Thin limestone and clastics deposited.
				135,000,000	
	Jurassic		46,000,000		Emergent conditions. Erosion, formation of rolling terrain.
				181,000,000	Deposition of fluvial clastics.
	Triassic		49,000,000		Erosion. Broad flood plain develops.
				230,000,000	
PALEOZOIC	Permian		50,000,000		Deposition of evaporite sequence followed by continental red beds.
					Sedimentation continous in Delaware, Midland, Val Verde basins and shelf areas.
				280,000,000	
	Pennsylvanian		30,000,000		Massive deposition of clastics. Shelf, margin, basin pattern of deposition develops.
				310,000,000	
	Mississippian		35,000,000		Regional tectonic activity accelerates, folding up Central Basin platform, Matador arch, ancestral Rockies.
					Regional erosion. Deep, broad basins to east and west of platform develop.
				345,000,000	
	Devonian		60,000,000		Renewed submergence.
					Shallow sea retreats from New Mexico; erosion.
				405,000,000	Mild epeirogenic movements. Tobosa basin subsiding. Pedernal landmass and Texas Peninsula emergent, until Middle Mississippian.
	Silurian		20,000,000	425,000,000	
	Ordovician		75,000,000		Marathon–Ouachita geosyncline, to south, begins subsiding.
					Deepening of Tobosa basin area; shelf deposition of clastics, derived partly from ancestral Central Basin platform, and carbonates.
				500,000,000	
	Cambrian		100,000,000		Clastic sedimentation – Bliss sandstone.
				600,000,000	
PRECAMBRIAN					Erosion to a nearly level plain.
					Mountain building, igneous activity, metamorphism, erosional cycles.

*There is no consensus on times and durations.

REF: DOE, 1980.

FIGURE 4.1

MAJOR GEOLOGIC EVENTS AFFECTING SOUTHEASTERN NEW MEXICO AND WESTERN TEXAS

These geologic events have developed the current southeastern New Mexico physiographic setting. The WIPP is located within the Pecos Valley section of the southern Great Plains physiographic province, a broad highlands that slopes gently eastward from the Basin and Range Province. (A more detailed discussion of the WIPP regional physiography is presented in FEIS Subsection 7.3.) The WIPP site and associated Permian evaporites are situated within the structural framework of the Delaware Basin. The Delaware Basin is a broad, oval, north-south-trending trough with a structural relief of more than 20,000 feet on top of Precambrian basement. Deformation of the basin rocks is minor. The basin was probably developed by early Pennsylvanian time and since that time the Upper Permian has undergone little tectonic activity. A general stratigraphic column and cross section are shown in Figure 4.2, and major regional structures are shown in Figure 4.3.

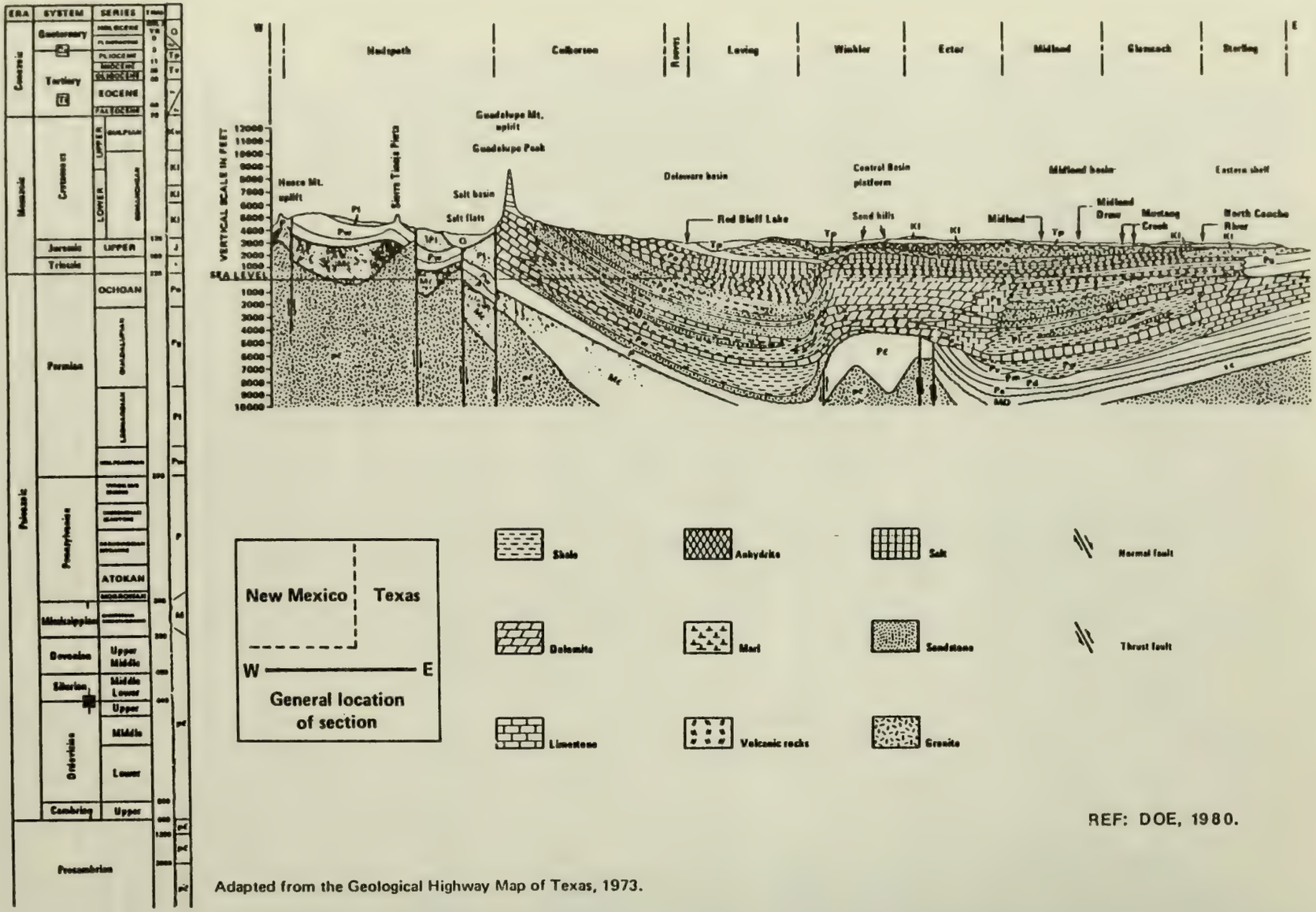
4.2.2 Stratigraphic Setting of the WIPP Site

As shown in Figure 4.3, the WIPP site is located in southeastern New Mexico, in the northern portion of the Delaware Basin. The generalized stratigraphy in the vicinity of the WIPP site is summarized in Figure 4.4. Regional stratigraphic relationships and characteristics are discussed in detail in FEIS Subsection 7.3.

The portions of the Permian stratigraphic column pertinent to the WIPP site are the upper Delaware Mountain Group and the overlying Upper Permian (Ochoan) formations (Figure 4.4). The Bell Canyon Formation, the uppermost formation in the Delaware Mountain Group, is the first regionally continuous, water-bearing formation beneath the WIPP repository horizon (about 2,000 ft). Near the WIPP site, the Bell Canyon Formation consists of a layered sequence of sandstones, shales/siltstones, and limestone of 980 ft or more in thickness. The sandstones and shales of the Bell Canyon Formation are overlain by the thick-bedded Permian sequence of anhydrite and halite of the Castile Formation.

The Castile Formation near the WIPP site normally contains three relatively thick units of anhydrite ($CaSO_4$) and carbonate ($CaCO_3$) and two thick strata of halite (NaCl). The salt and anhydrite units contain abundant anhydrite and/or carbonate laminae that may be strongly deformed internally and are variable in local thickness. The thickness of the Castile Formation near the WIPP site is approximately 1,310 ft.

Overlying the Castile Formation, the Salado Formation varies from 1,700 to 2,000 ft in thickness at and near the WIPP site (Figures 4.5 and 4.6). It contains 45 numbered "anhydrite" marker beds of variable thickness; these beds are designated MB101 through MB145, with the numbers increasing with increasing depth. Between marker beds, the Salado Formation consists of layered halite of varying purity, with accessory minerals. The dominant accessory minerals are anhydrite, clays, and polyhalite ($K_2MgCa_2(SO_4)_4 \cdot 2H_2O$). The middle portion of the Salado Formation contains potash deposits that are of commercial value. These materials are locally deposited approximately 980 ft above the underground WIPP site in the McNutt Potash Zone. The WIPP horizon is in the approximately 26-ft-thick halite bed bounded by Marker Beds 138 and 139. The WIPP horizon consists mostly of halite with a few thin interbeds of anhydrite, clay and polyhalite. A generalized stratigraphic cross section of the Salado and Castile Formations is shown in Figure 4.5.



REF: DOE, 1980.

Adapted from the Geological Highway Map of Texas, 1973.

FIGURE 4.2

GEOLOGIC COLUMN AND CROSS SECTION OF THE NEW MEXICO–TEXAS REGION

REF: DOE, 1980.

FIGURE 4.3

MAJOR REGIONAL STRUCTURES

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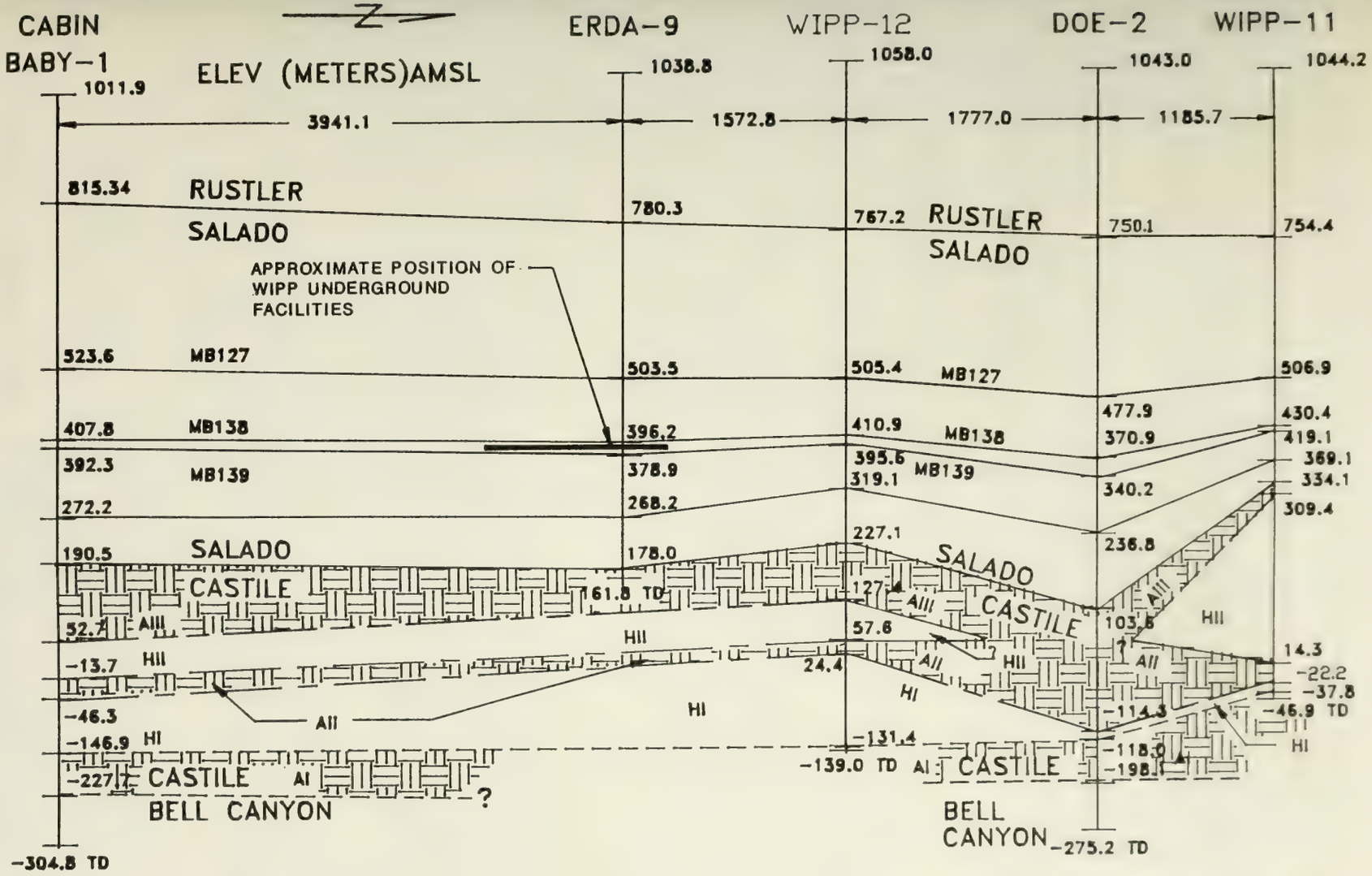
SYSTEM	SERIES	GROUP	FORMATION	MEMBER
RECENT	RECENT		SURFICIAL DEPOSITS	
QUATER-NARY	PLEISTO-CENE		MESCALERO CALICHE	
			GATUNA	
TRIASSIC		DOCKUM	UNDIVIDED	
PERMIAN	OCHOAN		DEWEY LAKE RED BEDS	
			RUSTLER	Forty-niner
				Magenta Dolomite
				Tamarisk
				Culebra Dolomite
				unnamed
			SALADO	
			CASTILE	
	GUADALUPIAN	DELAWARE MOUNTAIN	BELL CANYON	
			CHERRY CANYON	
			BRUSHY CANYON	

REF: BEAUHEIM, 1987c.

FIGURE 4.4
GENERALIZED STRATIGRAPHIC COLUMN FOR THE WIPP SITE



NOTES: 1) BOREHOLE LOCATIONS USED ARE SHOWN ON FIGURE 4.6.
2) ELEVATIONS AND BOREHOLE SPACINGS ARE IN METERS.

REF: LAPPIN, 1988.

FIGURE 4.5
GENERALIZED STRATIGRAPHIC CROSS SECTION OF THE SALADO AND CASTILE FORMATIONS BETWEEN BOREHOLES CABIN BABY-1 AND WIPP-11

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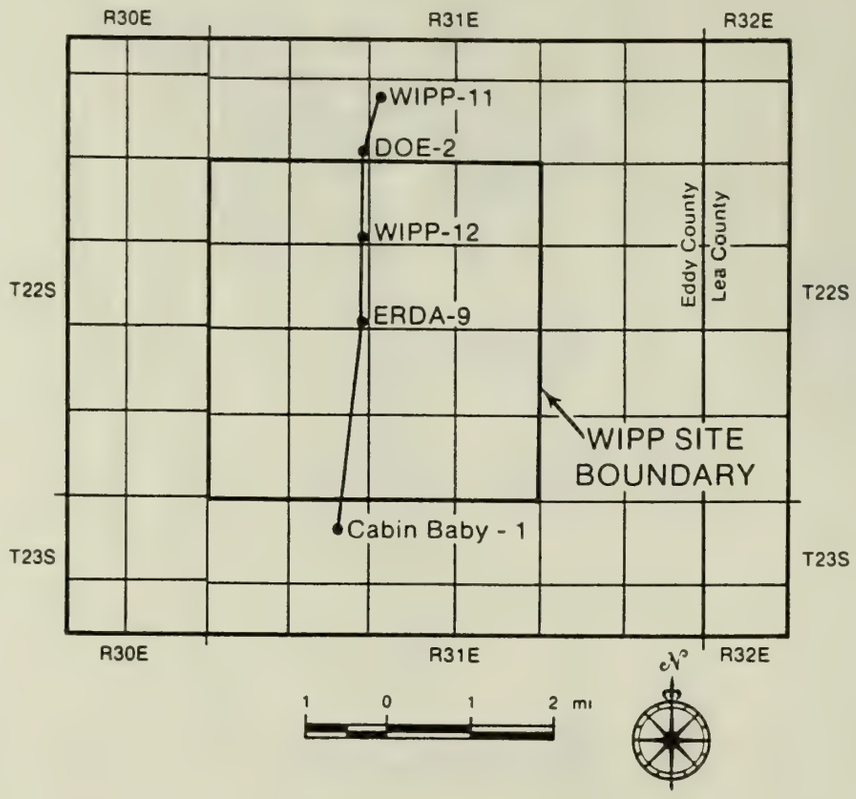


REF: LAPPIN, 1988.

FIGURE 4.6
BOREHOLE LOCATIONS FOR GENERALIZED STRATIGRAPHIC CROSS SECTION OF THE SALADO AND CASTILE FORMATIONS

The Salado Formation is overlain by the Rustler Formation, also of Ochoan age. The Rustler consists of varying proportions of anhyrdite, siltstone/claystone, halite, and carbonate. There are five water-bearing zones within it, rather than the three recognized at the time of the FEIS. In ascending order, these zones are the siltstone portion of the lower unnamed member and the Rustler/Salado contact; the Culebra Dolomite; the Tamarisk claystone; the Magenta Dolomite; and the Forty-Niner claystone. At and near the WIPP site, the Culebra Dolomite provides the predominant transport flow path. The Rustler Formation ranges from 270 ft to 430 ft in thickness at the WIPP site, depending on the extent of evaporite dissolution and/or depositional variability. The Rustler Formation at the WIPP is overlain by the Dewey Lake Red Beds (the uppermost unit of the Ochoan Series) consisting largely of siltstones and claystones, with subordinate sandstones. The unit is 100 ft to 560 ft thick at and near the WIPP site, varying at least in part due to postdepositional erosion.

4.3 HYDROLOGY AND WATER QUALITY

The following subsection describes the hydrologic and geochemical setting at the WIPP site. The purposes of SEIS Subsection 4.3.1, General Setting, are to provide a general overview of the WIPP site hydrology, to provide a summary of the hydrologic conclusions reached at the time of the FEIS, and to provide a description of the current understanding of hydrologic and geochemical issues. SEIS Subsections 4.3.2, 4.3.3, 4.3.4, and 4.3.5 discuss data collection and interpretation efforts conducted since 1980 and how these efforts apply to the hydrologic and geochemical conditions of the Salado, Rustler, Castile, and Bell Canyon formations. Subsection 4.3.2.4, Disturbed Rock Zone and Associated Fractures, has been added to this final SEIS in response to public comments.

4.3.1 General Setting

4.3.1.1 Hydrologic Overview. The WIPP is located in a portion of the Unglaciated Central Region that includes some of the least productive aquifers in the United States. Consequently, the low productivity and general aridity of the area puts even greater emphasis on using these marginal aquifers to the maximum benefit. Section 7 of the FEIS (DOE, 1980a) describes the regional hydrology and water quality in detail. This section should be referred to by the reader to set the context for an understanding of the WIPP site hydrology.

The geologic units of hydrologic interest to the WIPP site, in ascending order, include the Bell Canyon Formation of the Delaware Mountain Group, the thick-bedded sequence of anhydrites and halites of the Castile Formation, the thick-bedded, predominant halites of the Salado Formation (including the Facility Horizon), the Rustler Formation, and the overlying Dewey Lake Redbeds.

The Bell Canyon Formation is of interest because it is the first regionally continuous water-bearing unit beneath the WIPP. The Castile Formation provides a hydrologic barrier underlying the Salado Formation, though it may contain pressurized brine.

The Culebra Dolomite of the Rustler Formation is the first laterally continuous unit located above the WIPP underground facility to display hydraulic conductivity of any significance. Barring direct breach to the surface, the Culebra Dolomite provides the most direct pathway between the WIPP underground and the accessible environment. The hydrology and fluid geochemistry of the Culebra Dolomite are very complex and, as a result, have received a great deal of study in WIPP site characterization before and since 1980 (LaVenue et al., 1988; Haug et al., 1987). A map showing the borehole locations referred to throughout the following text is presented in Figure 4.7.

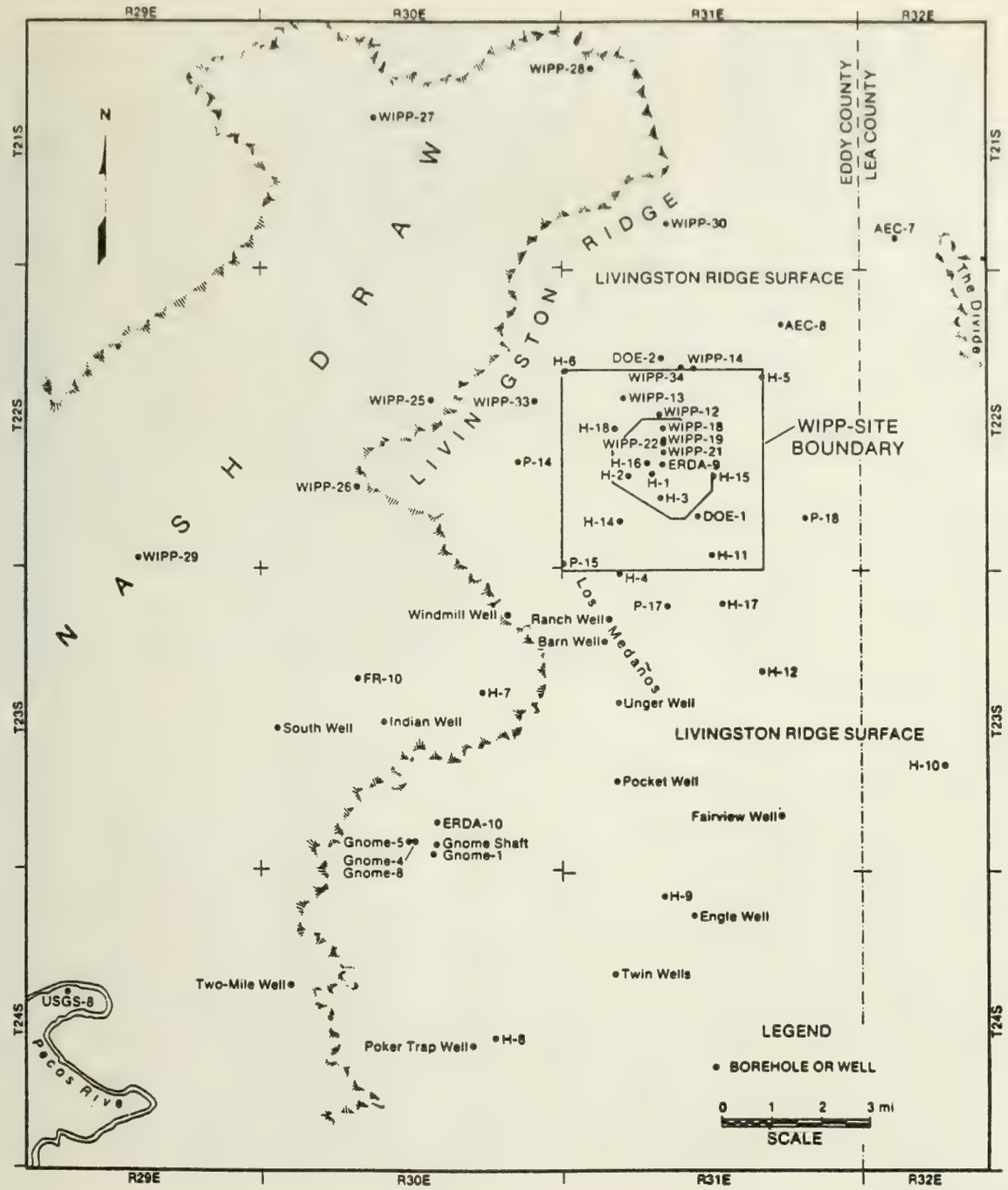
The Dewey Lake Redbeds rest unconformably on the Rustler Formation. They are the uppermost of the late Permian and Paleozoic rocks in the Delaware Basin. They are reddish-orange to reddish-brown siltstones and fine-grained sandstones. At the site, they are 60-ft below the surface and about 490-ft thick. These units appear to be hydrologically unsaturated in the vicinity of the WIPP site. These beds may act as a barrier against downward percolation of surface water with a resultant recharge of the Rustler and dissolution of underlying evaporites (Jones, 1954) .

4.3.1.2 Hydrologic and Geochemical Issues. A number of issues have been developed regarding the hydrogeologic and geochemical characteristics of the WIPP site. These issues were either considered in the FEIS or developed in response to new data generated by shaft exploration and excavation activities conducted since the completion of the FEIS. A summary of the hydrologic and geochemical issues, the assumptions made regarding these issues in the FEIS, and current understanding of these issues is presented in Table 4.1. The current understanding of the hydrologic and geochemical issues is incorporated into the analysis of potential long-term performance impacts discussed in Subsection 5.4.

4.3.2 Salado Formation

The Salado Formation is a major salt-bearing formation and is the horizon within which the WIPP underground facility is located. The FEIS assumed that the disposed waste would be compacted within the salt because of the stress-induced creep of salt (i.e., closure of the tunnels due to movement of the salt) and would remain dry because of the lack of interstitial fluids. The FEIS also assumed that the gas permeability of the salt would be sufficient to dissipate the gas generated by the waste. Subsequent to the FEIS, hydrologic investigations in the underground facility and hydrologic testing adjacent to the air intake shaft have provided additional information about these assumptions. The following subsections summarize the results of the hydrologic and geochemical studies of the Salado that have been completed since the FEIS. Subsection 4.3.2.1 discusses the current understanding of brine inflow and the gas-dissipation potential. Subsection 4.3.2.2 discusses the hydrologic testing that has been conducted in the WIPP underground facility. Subsection 4.3.2.3 summarizes the results of the hydrologic testing at the waste handling shaft. Subsection 4.3.2.4 discusses the characteristics of Marker Bed 139.

4.3.2.1 Brine Inflow and Gas Dissipation Potential. Brine-related studies that were completed at the time of the FEIS indicated that: 1) the only water present in Salado halites was in the form of fluid inclusions and hydrous minerals, and no intercrystalline brines were believed to be present; 2) any brine flow would be driven by temperature gradients with no long-term steady-state flow; and 3) there would be no need for engineered backfill within the repository to control brine inflow or interactions between



REF: LAPPIN et al., 1989.

FIGURE 4.7
HYDROLOGIC BOREHOLES AND WELLS
AT AND NEAR THE WIPP SITE

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TABLE 4.1 Hydrologic issues: FEIS vs. Current (Modifed from Lappin et al., 1989)

Hydrologic issue	Assumptions or treatment in the FEIS	Present understanding
1. Salado brine flow and brine permeability	a. Water assumed present only in fluid inclusions and hydrous minerals; grain boundaries assumed dry.	a. Grain-boundary brines distinct from fluid inclusions. Salado probably hydrologically saturated.
	b. Brine inflow only due to thermal gradients resulting from excavation and waste emplacement; very limited volumes, with zero flow at long times. Pressure gradients were not considered a driving mechanism for brine inflow.	b. Major factor is flow of grain-boundary fluids due to pore-pressure gradients resulting from excavation; experimental results to date modeled assuming Darcy flow, which implies nonzero long-term inflow; possible uncertainties due to stratigraphic effects, two-phase flow, and non-Darcy flow model recognized but not yet quantified; Darcy flow model probably overpredicts brine inflow, but still indicates brine-based slurry is highly improbable.
	c. Far-field brine permeability not relevant since unit interpreted to be unsaturated.	c. Far-field brine permeability probably less than 10^{-20} to 10^{-21} m^2; may be effectively zero in undisturbed region.
2. Salado gas permeability and gas storage properties	a. Far-field gas permeability of Salado salt considered; appeared adequate to dissipate the gas potentially generated by waste.	a. Far-field gas permeability probably less than 10^{-20} to 10^{-21} m^2, and grain-boundary brines pressurized to between hydrostatic and lithostatic pressure; very difficult to dissipate any significant volumes of gas generated within the underground workings, because of the extremely low permeability.
	b. No major concern with gas pressures within facility.	c. Combination of potential gas-generation rates and very low far-field permeability will probably result in gas pressures exceeding lithostatic load unless they are relieved by 1) room reexpansion; 2) gas storage in disturbed-rock zone adjacent to underground workings; 3) gas storage in Marker Bed 139 and along other stratigraphic contacts near the WIPP facility horizon; and/or 4) a combination of gas migration past the panel seals and up shafts into adjacent marker beds.
3. Salado brine geochemistry	a. Intergranular brines not recognized; brines A and B defined for experimental purposes; brine A is K, Mg-rich, brine B is high NaCl brine. Neither one was from the repository level.	a. Considerable variability of Salado brines identified; standard brine identified is similar to brine B, but less rich in K and Mg, higher in Na, Cl and B; brine standard defined appears to be near saturation with anhydrite, gypsum, and halite; brines collected within WIPP underground workings often evolve gas, thought to be mainly nitrogen.
4. Hydrology of the Castile Formation; presence and character of Castile brine reservoir beneath WIPP underground workings	a. Castile brines known at drill holes ERDA-6 and Belco, but the FEIS concluded that Castile brine was probably not present beneath underground workings; effects of pressurized-brine occurrence in the Salado considered qualitatively.	a. Pressurized brines are assumed to be present beneath WIPP waste emplacement panels, based on data from combination of drill holes and geophysical studies; properties of brine occurrence are assumed to be those interpreted for the WIPP-12 reservoir.
5. Hydrology of the Bell Canyon Formation and relationship of the hydraulic heads of the Bell Canyon and Rustler	a. Although possibility of downward flow was recognized, it was assumed that flow after the interconnection of the Bell Canyon and the Rustler would be upward into the Rustler (FEIS scenario).	a. Based on interpretation of relative heads at drill holes Cabin Baby-1 and DOE-2, it is concluded that flow would be downward if Bell Canyon and Rustler were interconnected; due to low local permeability of Bell Canyon, flow in this unit would be very slow and is not considered here.

TABLE 4.1 Concluded

Hydrologic issue	Assumptions or treatment in the FEIS	Present understanding
6. Rustler Formation hydrology, geochemistry, and numerical modeling	a. Three water-bearing zones recognized, based on testing at eight locations.	a. A total of 41 locations tested to date, indicating presence of five water-producing units.
	b. Culebra and Magenta Dolomites known to range widely in transmissivity, but thicknesses were combined for purposes of numerical modeling; uniform transmissivity to Rustler Formation, as an integrated hydrostratigraphical unit, was assigned in WIPP site area.	b. Culebra Dolomite still interpreted to dominate flow in site area. Culebra transmissivity variable by approximately three orders of magnitude within the WIPP site; total range of reported transmissivities (T) from $\leq 2 \times 10^{-7}$ m^2/s to $>10^{-3}$ m^2/s (Lappin et al., 1989); all measured transmissivities included as point values in numerical estimates of transmissivity distribution; zone of relatively high transmissivities present in southeastern portion of site; final regional-scale testing of the Culebra Dolomite completed in 1988, interpretation completed in 1989.
	c. Culebra Dolomite known to be locally fractured, but modeled as porous medium with uniform porosity of 0.10.	c. Local flow and transport behavior affected by fracturing where $T \geq 10^{-6}$ m^2/s; distances over which fracturing plays a role dependent on local properties, especially in southeastern part of site; under some conditions fractures may dominate transport to location outside the site area; measured matrix porosities range from 0.03 to > 0.3 (Lappin et al., 1989).
	d. Flow within Culebra interpreted to be essentially north-south in site area, with final discharge at Malaga Bend, southwest of the WIPP site; interpretation based on modeling of flow from interpreted freshwater heads.	d. Modern flow within Culebra interpreted to be largely north-south in site area, but dominated by flow in zone of relatively high transmissivity in southeastern portion of site; ultimate discharge not clear at present; interpretation based on modeling which includes effects of variable brine density.
	e. Head potential known to vary across hydrostratigraphic units; however, it was assumed for numerical modeling that Rustler carbonates were completely confined and at steady state.	e. Head potentials between units known to be laterally variable; limits to vertical flow considered qualitatively; present modeling assumed confined steady-state flow on 10,000 year time scale, except for disturbance due to Castile brine reservoir; however, it is recognized that Rustler hydrologic setting is transient on 10,000-year time scale; where defined, relative head potentials and geochemistry within Rustler not consistent with modern infiltration from surface at WIPP.
	f. Rustler water salinity known to be variable (3,000 to 60,000 ppm TDS[a]), but effects could not be considered in numerical modeling.	f. Total range of TDS in Rustler waters at the WIPP site estimated as 4,000 to > 300,000 mg/L, Culebra waters range from approximately 10,000 to > 200,000 mg/L; need for careful and repetitive sampling of groundwaters recognized.

[a] TDS = total dissolved solids.

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brine and the waste. Since the FEIS, subsurface information gathered following the opening of the WIPP underground workings indicates that the Salado halites may be saturated. Saturation of the Salado halites has also been postulated by Bredehoeft (1988). Test excavations into the target horizon showed that brine "weeps" often formed on mined faces within a few days of excavation and that salt crusts continued to form on open faces for months (Deal and Case, 1987). Based on these measurements, Deal and Case (1987) and Deal et al. (1987) estimated flow rates ranging from a few milliliters to 0.5 L/day. Nowak and McTigue (1987) estimated an average steady-state flow of about 1.6 ml/day/m^2.

Mine ventilation evaporates the brine inflow in almost all areas of the underground workings and would continue to do so as long as the underground workings remain open. Also, long-term observations show that most inflows decrease markedly over time and many cease entirely. However, because of the very slow response times, steady-state flow conditions may be determinable only from many years of observation (Deal, et al., 1987, Deal, 1988).

A variety of investigations have been undertaken within the WIPP underground facility since the FEIS. Many of these studies were conducted as part of agreements between the DOE and the State of New Mexico. The most recent Agreement for Consultation and Cooperation, dated March 22, 1988, includes 1) hydrological characterization of the Rustler Formation, 2) laboratory studies related to sorption, 3) documentation of pressurized-brine occurrences, and 4) assessment of the effect of the shafts on Rustler hydrology. Geophysical studies aimed at characterizing the disturbed rock zone near the excavation began during construction and would continue through the Disposal Phase. Available results (Borns and Stormont, 1988; Pfeifer, 1987) indicate that there is variability in both the water content and the hydrologic properties of the Salado Formation near the underground excavations, and that the water content of Salado salts far from the excavations appears to be approximately twice that estimated at the time of the WIPP studies in the Site Preliminary Design Validation (SPDV) phase.

The results of a series of electrical conductivity measurements in the WIPP underground horizon (Pfeifer, 1987) indicate a water content of approximately 1 percent (by weight) near the mined opening and 2 percent in the far field. However, only a fraction of this water may be mobile as brine inflow under repository pressure gradients (Deal and Case, 1987).

Deal et al., (1987) evaluated moisture content measurements made on samples from the stratigraphic units exposed in the WIPP excavations and from drillholes in the workings. Sixty of these were collected from ribs using a hand-held core drill. Cores were about 4 centimeters in diameter and 15 centimeters long. These cores show a distinct correlation between moisture content and stratigraphy.

The moisture content of the facility-horizon rocks was determined by the weight lost when they were heated to 95°C. The loss ranged from 0.03 to 2.53 percent by weight. Samples from clay-rich stratigraphic horizons were more moist than those from clear halite horizons and also were more variable in moisture content from location to location within a given horizon. Specimens from the "orange band" (a thin, colored layer of halite visible in the walls of tunnels) were consistently the least moist.

Data from cores taken from vertical drillholes also indicated that some stratigraphic horizons are more moist than others. However, only a few samples exist from some horizons. Preliminary data indicate, however, that there are zones within the salt that contain more moisture than the anhydrite interbed. This contrasts with the observation that in many places more moisture appears to seep from the anhydrite beds than from the salt.

Deal et al. (1987) reported that for samples consisting predominantly of halite, the measured moisture content was approximately 0.5 percent by weight or less. Rocks with a higher clay content had a greater tendency for large, less predictable ranges and were generally more moist. The variation in moisture content will be refined as additional moisture content measurements are made.

Several studies have been undertaken to characterize brine flow into the facility. Deal and Case (1987) and Deal et al. (1987) have reported on a long-term study, the Brine Sampling and Evaluation Program (BSEP), designed to evaluate inflow at ambient temperatures. Nowak and McTigue (1987) also provide ambient-temperature inflow data. The BSEP studies indicated that variable amounts of both brine and dissolved gas can be intersected in drillholes extended from the WIPP. The maximum flow rate encountered has been approximately 0.5 L/day. One drillhole produced approximately 235 liters of brine at a rate of 0.2 L/day. This hole apparently intersects Marker Bed 139, which contains numerous near-field fractures that have resulted from the construction of the WIPP. Most of the measured flow rates ranged from a few thousandths to a few tenths of a liter per day.

Nowak and McTigue (1987) investigated flow into one 36-inch- and three 30-inch-diameter holes. Liquid was continuously removed from the holes by the use of dry nitrogen. The results indicate a flux of approximately 1.5 $cm^3/day/m^2$ of excavation wall. These brine-inflow rates were used as a basis to estimate hydraulic conductivities for the near-field WIPP Salado host rock. Using a Darcy flow model and assuming a porous and elastic medium, permeabilities of 10^{-20} to 10^{-21} m^2 (approximately equivalent to hydraulic conductivities in the ranges of 10^{-13} to 10^{-14} m/sec) were estimated (Lappin et al., 1989; Nowak and McTigue, 1987; Nowak et al., 1988).

Additional calculations based on direct in situ hydraulic conductivity investigations indicate that the FEIS may have greatly overestimated the far-field hydraulic conductivity of the Salado Formation. Current estimates of the far-field hydraulic conductivity, based on direct measurements at the waste handling shaft and in the test rooms, indicate that the estimated permeability values are in the range of 10^{-20} to 10^{-22} m^2 (approximately equivalent to hydraulic conductivities of 10^{-13} to 10^{-15} m/sec) (Lappin et al., 1989; Peterson et al., 1987; Saulnier and Avis, 1988; Tyler et al., 1988). A more detailed discussion of Salado permeability testing and brine-inflow data is presented in Appendix E.

Although these test results indicate that the permeability and the brine content of the Salado are very low, a final understanding of the hydraulic characteristics of the Salado Formation has not yet been clearly defined. The hydraulic uncertainties include: 1) whether the driving mechanism for brine flow is a far-field-driven hydraulic system or a system limited to the disturbed rock zone, where mining-induced pressure gradients drive the brine through zones of increased local permeability due to fracturing; 2) whether a gas-driven, two-phase behavior is a factor; and 3) whether a porous-medium

(Darcy) flow or a non-Darcy flow is the predominant process. Darcy flow models have been generally consistent with experimental data collected to date, although the duration of underground observation has not been sufficient to distinguish between Darcy and non-Darcy flow.

In response to these uncertainties, several conceptual models are proposed for brine inflow. These conceptual models include a conventional Darcian flow model (see, for example, Bredehoeft, 1988; Nowak et al., 1988) that assumes a porous and elastic medium, a Darcian flow model that considers changes of porosity and permeability with respect to time and space (Niou and Deal, 1989), and a non-Darcian model that assumes non-Newtonian fluid flow in the rock salt and in which the source of flow is limited to the bedded evaporites that have been disturbed by the WIPP underground excavations. In the non-Darcian conceptual model, the flow of brine into the WIPP underground facility may decrease to zero prior to the saturation of the WIPP rooms and panels. The conventional flow model (which includes flow throughout the Salado Formation) may be a conservative model in that it assumes that far-field flow exists and predicts maximum brine accumulations (i.e., potential saturation of the WIPP excavation at some time after the WIPP is closed). The results obtained with the conventional brine-inflow model are presented in Subsection 5.4.2.4.

A recent concern related to brine inflow is that the compaction of the waste within the disposal rooms will be incomplete or interrupted and that brine will mix with the waste to form a slurry. The slurry is envisioned as a watery mixture of insoluble matter that is easily transported through natural or man-induced pathways. The formation of waste mixtures with such fluidity is very unlikely (see Subsection 5.4.2.4). The brine-inflow modeling indicates that the backfill and the waste will reach a sufficiently compacted state to become solid-like before they become saturated in brine.

The most important potential response to brine inflow is the generation of gas from the waste materials. If sufficient brine is present, the combination of microbial activity, canister corrosion, metal-waste corrosion, and radiolysis will produce large quantities of gas. Gas generation may create a situation where the repository rooms are unsaturated with brine but are pressurized by gas to levels approaching those of lithostatic pressure. The current brine-inflow estimates indicate that sufficient quantities of brine will be available for gas generation. However, it should be noted that current estimates are conservative because of parameter-value selections and because of fundamental model assumptions. If brine-inflow rates are significantly lower than the current estimates, gas production may be limited, and the final repository state may be quite different from an ultimately saturated pressurized system. In order to predict the final state of the repository with a high level of confidence, brine inflow would be characterized as fully as possible during the Test Phase.

This leads to the second issue of concern in the Salado Formation, the potential for dissipation of waste-generated gas during the postclosure period. If gas pressures approach lithostatic levels within the repository, and if seals at the repository level are not by-passed, fractures are expected to form (when the least principal stress is exceeded in the surfaces of the excavations) and propagate into the Salado Formation. Results from fracturing experiments by Wawersik and Stone (1986) indicate that there was no preferential direction for fracture propagation, though at the WIPP horizon, previously fractured zones like Marker Bed 139 may provide a preferential pathway for gas migration.

For pressures approaching lithostatic levels to develop, assuming that gas generation will occur, far-field permeabilities must be at or near zero. At the time the FEIS was published, the far-field gas permeability of the Salado Formation appeared sufficient to dissipate waste-generated gas pressures. Current information concerning the gas-transport properties of the Salado Formation indicates that the far-field permeabilities may be even lower than the present estimate (10^{-20} to 10^{-22} m^2) and significantly less than previously estimated. (See earlier discussion regarding permeabilities.) Consequently, the far-field permeability values for the Salado Formation may not be sufficient to dissipate generated gas pressures within the WIPP to levels less than those of lithostatic pressures, should conditions be favorable for the generation of large volumes of gas.

One key to understanding the final state of the repository with regard to gas pressure and degree of saturation is further detailed characterization of brine inflow. Additional investigations would be conducted during the Test Phase to refine the understanding of Salado far-field permeabilities and brine inflow. Additional discussions of brine inflow, slurry development, and gas generation are presented in Subsection 5.4.2.4.

4.3.2.2 Hydrologic Testing of the Salado Formation at the Facility Horizon. The permeability characteristics of the Salado Formation need to be understood in order to predict brine-inflow rates and to evaluate the extent to which gas pressures can be dissipated. At the time the FEIS was written, hydraulic tests had been conducted in the Salado Formation at two locations, drillholes ERDA-9 and AEC-7 (DOE, 1980a; Tyler et al., 1988). The permeability values estimated from these tests ranged from 10^{-17} to 10^{-18} m^2 (approximately equivalent to hydraulic conductivities values of 10^{-10} to 10^{-11} m/sec). After the excavation of the WIPP underground facility, a number of inflow or permeability tests were conducted at the facility horizon. The brine-inflow tests were discussed above) in Subsection 4.3.2.1 (Deal and Case, 1987; Nowak and McTigue, 1987). The gas-permeability tests reported by Peterson et al. (1987) will be briefly discussed here. A more detailed presentation of post-FEIS Salado Formation permeability testing data is in Appendix E. Results of permeability testing within the Salado Formation from test installations within the WIPP are generally consistent with estimates of far-field permeabilities that range from 10^{-20} to 10^{-22} m^2 (hydraulic conductivity values that of 10^{-13} to 10^{-15} m/sec). The results of these tests are consistent in that they indicate far-field permeabilities in the Salado Formation to be 1,000 to 10,000 times lower than those assumed at the time of the FEIS. The pre-FEIS surface permeability tests in the Salado (drillholes ERDA-9 and AEC-7) were re-evaluated and determined not defensible for a number of reasons, including the following: 1) the pressure-stabilization periods preceding the tests were too short to allow adequate equilibration between borehole and formation pressure; 2) individual tests were also too short to allow representative formation responses to develop; and 3) the formation pore space was assumed to be filled with gas (Lappin et al., 1989).

Gas-flow permeability tests that were conducted at the WIPP underground facility can be grouped into three sets: 1) 1984 tests, 2) tests in the N1420 drift, and 3) tests in the first storage panel. Gas-flow tests were conducted from horizontal, vertical, and angular boreholes drilled from WIPP drifts. The results of these tests are presented in Tables 4.2 through 4.5. It should be noted that most of these tests were conducted

TABLE 4.2 Summary of 1984 Phase 2 underground facility gas flow test results (modified from Stormont et al., 1987)

	Hole number	Orientation	Location with respect to tunnel	Geologic features	Test interval (m) Distance from tunnel			Permeability analysis		
					Minimum	Maximum	Mean	Transient method K(μD)	Porosity	Steady-state method K(m^2)
1	4PD01	Down	Center	Marker bed	1.2	2.8	2.00	NA[a]	NA	$> 9.87 \times 10^{-13}$
2	4PD02	Down	Near side	Marker bed	1.5	2.8	2.15	NA	NA	$< 9.87 \times 10^{-18}$
3	4PU04	Up	Center	Seam B	1.3	3.4	2.35	NA	NA	9.87×10^{-16}
4	4PU01	Up	Near side	Seam B	2.8	4.3	3.55	NA	NA	$< 9.87 \times 10^{-18}$
5	4PU02	Up	Center	Seam A	3.4	5.0	4.20	NA	NA	$< 9.87 \times 10^{-18}$
6	DPD01	Down	Removed	Marker bed	9.3	12.5	10.90	NA	NA	$< 9.87 \times 10^{-18}$

[a] Not applicable.

TABLE 4.3 Summary of N1420 initial tests (modified from Stormont et al., 1987)

	Hole number	Orientation	Location with respect to tunnel	Geologic features	Test interval (m) Distance from tunnel			Permeability analysis		
					Minimum	Maximum	Mean	Transient method K(μD)	Porosity	Steady-state method K(m^2)
1	NPD02	Down	Center	Marker bed	1.0	2.6	1.80	NA[a]	NA	2.96×10^{-16}
2	NPD05	Down	Center	Marker bed	1.0	2.8	1.90	NA	NA	4.94×10^{-17}
3	NPD05	Down	Center	Marker bed	1.0	2.8	1.90	NA	NA	8.39×10^{-17}
4	NPD04	Down	Center	Marker bed	1.0	2.9	1.95	NA	NA	5.13×10^{-17}
5	NPD06	Down	Intersect	Marker bed	1.0	2.9	1.95	NA	NA	8.29×10^{-14}

[a] Not applicable.

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TABLE 4.4 Summary of N1420 follow-up (modified from Stormont et al., 1987)

	Hole number	Orientation	Location with respect to tunnel	Geologic features	Test interval (m) Distance from tunnel			Permeability analysis		
					Minimum	Maximum	Mean	Transient method K(μD)	Porosity	Steady-state method K(m^2)
1	L2CU1	Up	Center	Seam B	1.1	2.8	1.95	NA[a]	NA	$> 3.95 \times 10^{-12}$
2	NPU01	Up	Center	Halite rocks	0.5	0.9	0.65	NA	NA	$< 8.59 \times 10^{-17}$
3	NPD05	Down	Center	Halite rocks	0.4	0.8	0.60	NA	NA	$< 7.90 \times 10^{-20}$
4	NPD04	Down	Center	Halite rocks	0.5	0.9	0.65	NA	NA	$< 2.66 \times 10^{-19}$
5	NPD03	Down	Center	Halite rocks	0.3	0.7	0.50	NA	NA	$< 5.13 \times 10^{-15}$
6	2PD01	Down	Center	Halite rocks	0.4	0.8	0.55	NA	NA	$< 1.78 \times 10^{-15}$
7	NPD12	Down	Center	Halite rocks	0.4	0.8	0.55	NA	NA	$< 6.81 \times 10^{-17}$
8	NPD07	Down	Intersect	Halite rocks	0.4	0.8	0.55	NA	NA	$< 3.26 \times 10^{-16}$
9	NPD06	Down	Intersect	Halite rocks	0.4	0.8	0.57	NA	NA	$< 3.16 \times 10^{-15}$
10	NPD09	Down	Removed	Halite rocks	0.5	0.9	0.65	NA	NA	$< 1.38 \times 10^{-17}$
11	NPD08	Down	Near side	Halite rocks	0.5	0.9	0.65	NA	NA	$< 1.48 \times 10^{-13}$
12	NPD02	Down	Center	Halite rocks	0.5	0.9	0.65	NA	NA	$< 5.53 \times 10^{-15}$
13	NPD01	Down	Center	Halite rocks	0.5	0.9	0.65	NA	NA	$< 1.58 \times 10^{-18}$
14	L2CU1	Up	Center	Halite rocks	0.5	0.9	0.67	NA	NA	$< 3.36 \times 10^{-15}$
15	NPD02	Down	Center	Marker bed	1.0	2.5	1.75	NA	NA	8.59×10^{-16}
16	NPD02	Down	Center	Marker bed	1.0	2.5	1.75	NA	NA	7.50×10^{-16}
17	NPD03	Down	Center	Marker bed	1.0	2.7	1.85	NA	NA	4.05×10^{-18}
18	NPD05	Down	Center	Marker bed	1.0	2.8	1.90	NA	NA	5.53×10^{-16}
19	NPD05	Down	Center	Marker bed	1.0	2.9	1.90	NA	NA	3.26×10^{-16}
20	2PD01	Down	Center	Marker bed	1.0	2.9	1.95	NA	NA	$> 3.95 \times 10^{-12}$
21	NPD12	Down	Center	Marker bed	1.0	2.9	1.95	NA	NA	1.38×10^{-17}
22	NPD07	Down	Intersect	Marker bed	1.0	2.9	1.95	NA	NA	$> 3.95 \times 10^{-12}$
23	NPD06	Down	Intersect	Marker bed	1.0	2.9	1.95	NA	NA	$> 3.95 \times 10^{-12}$
24	NPD04	Down	Center	Marker bed	1.0	2.9	1.95	NA	NA	2.66×10^{-16}
25	NPD09	Down	Removed	Marker bed	1.0	3.0	2.00	NA	NA	3.45×10^{-19}
26	NPD08	Down	Near side	Marker bed	1.0	3.7	2.35	NA	NA	$< 6.81 \times 10^{-20}$
27	NPD01	Down	Center	Marker bed	1.0	3.7	2.35	NA	NA	4.15×10^{-17}
28	NPU01	Up	Center	Seam B	1.0	4.3	2.65	NA	NA	9.18×10^{-16}
29	NPU01	Up	Center	Seam B	1.0	4.3	2.65	NA	NA	2.37×10^{-16}
30	NPD10	Down	Removed	Marker bed	1.0	4.7	2.85	NA	NA	$< 8.59 \times 10^{-20}$

[a] Not applicable.

TABLE 4.5 Summary of first panel tests[a]

	Hole number	Orientation	Location with respect to tunnel	Geologic features	Test interval (m) Distance from tunnel			Permeability analysis		
					Minimum	Maximum	Mean	Transient method K(μD)	Porosity	Steady-state method K(m^2)
1	SPD06	Down	Center	Marker bed	1.3	3.3	2.30	NA[b]	NA	1.28×10^{-17}
2	SPU01	Up	Center	Seam B	1.3	3.3	2.30		Produced gas	
3	SPU06	Up	Center	Seam B	1.3	3.3	2.30		Produced gas	
4	SPU02	Up	Center	Seam B	1.3	3.3	2.30		Produced gas	
5	SPU05	Up	Center	Seam B	1.3	3.3	2.30		Produced gas	
6	SPD02	Down	Center	Marker bed	1.3	3.3	2.30	NA	NA	6.71×10^{-20}
7	SPD05	Down	Center	Marker bed	1.3	3.3	2.30	NA	NA	2.76×10^{-17}
8	SPD01	Down	Center	Marker bed	1.3	3.3	2.30	NA	NA	$< 2.96 \times 10^{-19}$
9	SPU04	Up	Center	Seam B	1.3	3.3	2.30	NA	NA	2.17×10^{-19}
10	SPU03	Up	Center	Seam B	1.3	3.3	2.30		Produced gas	
11	SPD04	Down	Center	Marker bed	1.3	3.3	2.30	NA	NA	6.42×10^{-19}
12	SPD03	Down	Center	Marker bed	1.3	3.3	2.30	NA	NA	1.28×10^{-19}

[a] Modified from Stormont et al., 1987, Table C.5.

[b] Not applicable.

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a relatively short distance from the underground facility and clearly show the effects of the disturbed rock zone. The conclusions that can be drawn from these tests are also presented in Appendix E.

The brine-inflow test boreholes, the waste handling shaft tests described in the following subsection, and the few gas-flow tests that may have intercepted far-field conditions represent a limited data base for the characterization of the hydraulic properties of the Salado Formation. Currently, a plan for an extensive Test Phase is being developed. Included in this plan is a description of the hydraulic investigation program (i.e., far-field brine-inflow tests, room tests, etc.) that is needed to understand the hydraulic characteristics of the Salado Formation.

4.3.2.3 Hydrologic Testing Adjacent to the WIPP Waste Handling Shaft. A preliminary series of hydrologic tests was conducted at several levels in the WIPP waste handling shaft in 1987 (Saulnier and Avis, 1988) to evaluate the hydraulic characteristics of both the Salado Formation and the unnamed lower member of the Rustler within the vicinity of a shaft. The objectives of these tests were to:

- Evaluate the extent of the disturbed rock zone extending from the concrete liner of the shaft
- Estimate the pressure and the radial extent of the hydrologic response to the stresses induced by shaft construction
- Estimate the far-field hydraulic properties of the lower unnamed member of the Rustler Formation and selected levels in the Salado Formation.

The tests were conducted at depths of 782 and 805 ft in the unnamed member of the Rustler Formation and at depths of 850 and 1,320 ft in the Salado Formation. The materials tested in the Rustler Formation included mudstone and claystone. The materials tested in the Salado Formation included halite, anhydrite, and polyhalite. Testing was conducted at drillholes, extending laterally into three test zones: Zone 1 extended from approximately 18 to 42 ft from the shaft, Zone 2 extended from approximately 12 to 20 ft, and Zone 3 extended from approximately 5 to 15 ft. The instrumentation used during the testing is described by Stensrud et al. (1988).

The results of the hydraulic testing at the waste handling shaft are summarized in Table 4.6 and Figures 4.8 and 4.9. The range of hydraulic-conductivity values presented on Table 4.6 is narrow, and the values are on the order of those expected in the far field (10^{-13} to 10^{-15} m/s). No discernible trend of an increase in hydraulic conductivity from Zone 1 to Zone 3 exists on the basis of these relatively short-term tests. The results of the testing appear to indicate that no disturbed rock zone exists (i.e., no more than 5 ft into the rock) as the result of shaft construction.

Table 4.6 Summary of the results of 1987 hydrologic testing in the WIPP waste handling shaft[a]

Borehole	Lithology	Test Zone depth interval (ft from shaft wall)	Pressure pulse (psi)	Hydraulic conductivity (m/s)	Formation pressure (psi)
W782W	Silty mudstone	1) 18.6-26.0	113.3	1.0×10^{-13}	90
		2) 12.3-15.9	108.3	1.0×10^{-14}	140
		3) 5.4-9.5	99.4	1.0×10^{-14}	140
W805W	Silty claystone	1) 18.6-26.0	94.5	5.0×10^{-14}	225
		2) 12.3-15.9	105.1	1.0×10^{-14}	140
		3) 5.4-9.5	97.8	1.0×10^{-14}	110
W805SW	Silty claystone	1) 18.6-26.5	102.9	6.0×10^{-15}	275
		2) 12.3-15.9	NA	1.0×10^{-15}[b]	90[b]
		3) 5.4-9.5	92.6	2.0×10^{-14}	70
W850W	Halite	1) 18.6-26.0	97.6	1.0×10^{-13}	40
		2) 12.3-15.9	116.5	1.0×10^{-13}	40
		3) 5.4-9.5	90.34	Not analyzable	--
W850SE	Halite	1) 23.2-36.0	103.5	3.0×10^{-14}	50
		2) 16.8-20.5	103.1	3.0×10^{-14}	30
		3) 10.0-14.1	100.7	2.0×10^{-14}	90
W1320E	Halite/ Anhydrite Polyhalite	1) 18.6-41.8	173.3	2.0×10^{-14}	550
		2) 12.3-15.9	52.6	3.0×10^{-14}	450
		3) 5.4-9.5	53.0	3.0×10^{-14}	100

[a] From Saulnier and Avis (1988).

[b] Zone 2 analysis from pressure buildup after shut-in, August 28 to 31, 1987.

NA = not available

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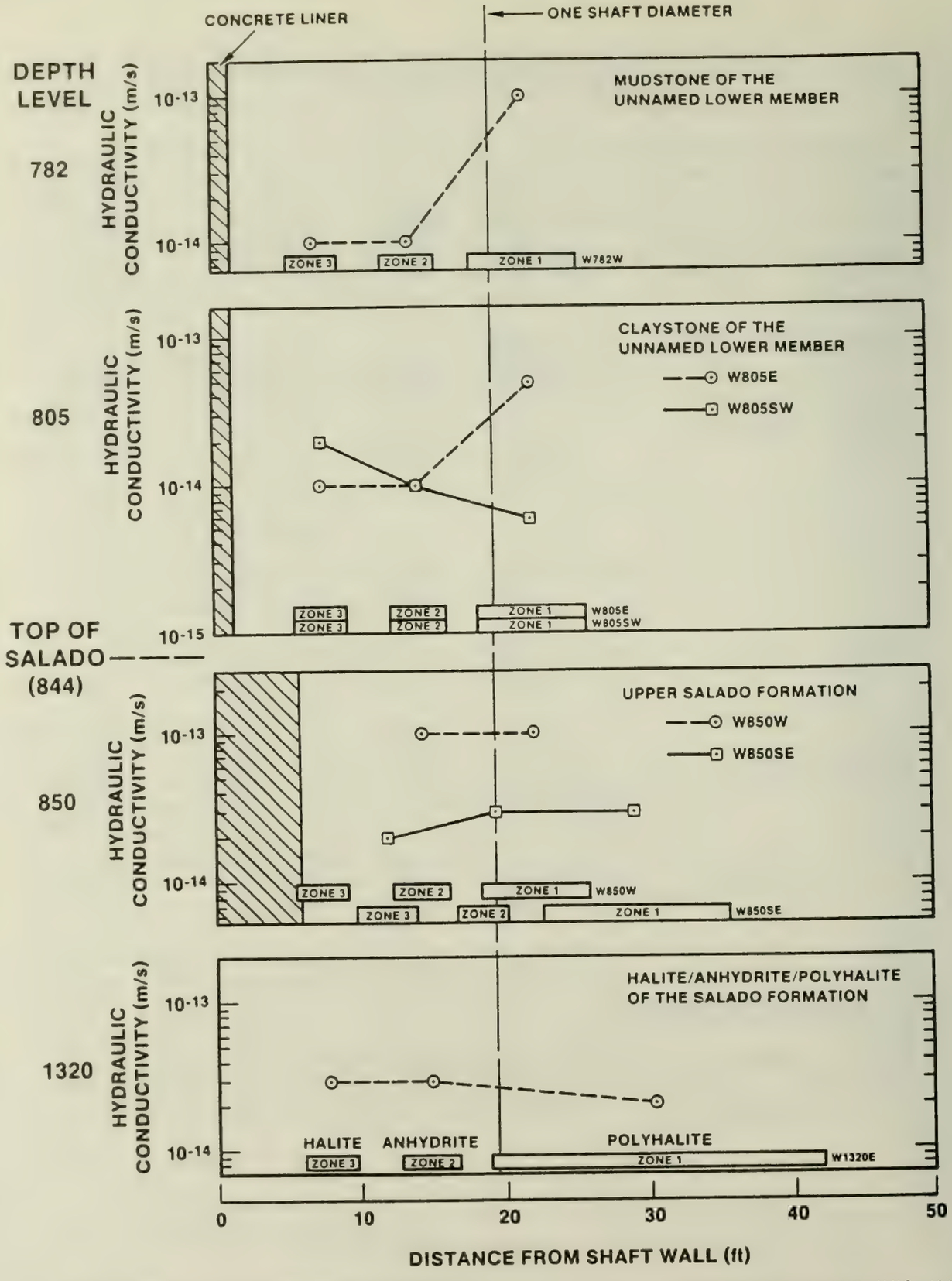
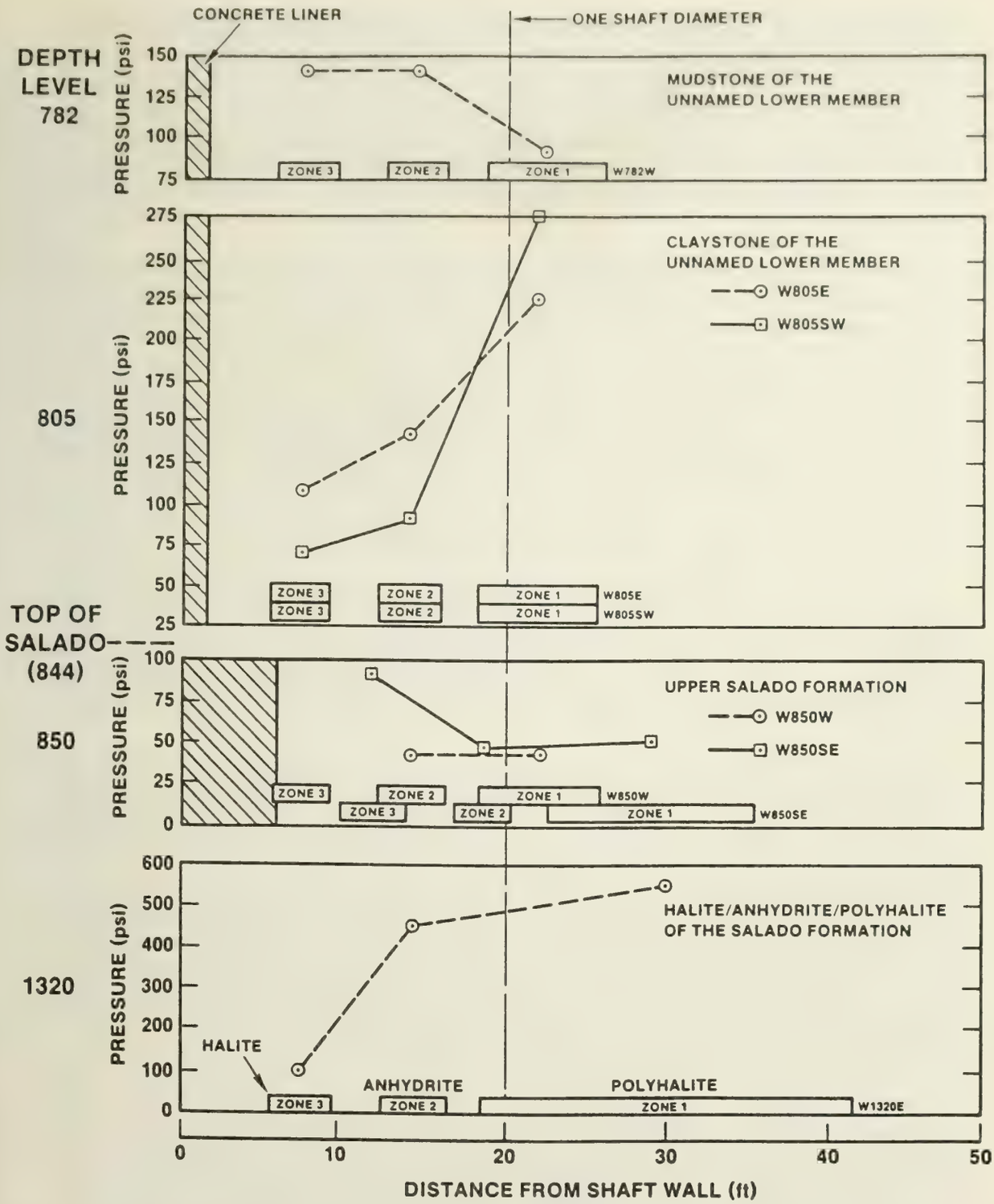


NOTE: DETERMINED IN 1987 TESTING IN THE WIPP WASTE HANDLING SHAFT.

REF: SAULNIER AND AVIS, 1988.

FIGURE 4.8
SUMMARY OF FORMATION CONDUCTIVITIES



NOTE: DETERMINED IN 1987 TESTING IN THE WIPP WASTE HANDLING SHAFT.

REF: SAULNIER AND AVIS, 1988.

FIGURE 4.9
SUMMARY OF FLUID FORMATION PRESSURES

Shaft construction has apparently formed a cone of depression in the hydraulic systems in the units adjacent to the waste handling shaft. Fluid pressures measured around the shaft at the 805- and 1,320-ft levels indicate that lowered pressures extend outward approximately one shaft diameter (Figure 4.9). The pressure release is consistent with responses noted in the Culebra Dolomite during the construction of exploratory shafts (Haug et al., 1987). Saulnier and Avis (1988) report that fluid-pressure profiles at the 782-ft and 850-ft levels may not be reliable because of possible equipment malfunctions.

The results of this shaft hydrologic testing program indicate a limited zone of disturbance in the vicinity of the shaft. Multiple arrays of test holes and possibly non-intrusive geophysical methods could provide additional data (Lappin, 1988).

4.3.2.4 Disturbed Rock Zone and Associated Fractures

Introduction. In response to the mining of an underground excavation, a zone of stress influence is developed that extends outward from the excavation to a distance of five-to-six times the radius of the opening (Brady & Brown, 1985). The redistribution of stresses within this zone of influence leads to the development of shear and tensile stresses that form fractures that make up a disturbed rock zone (DRZ).

The potential for a DRZ to develop around the WIPP underground workings was not considered in the FEIS, although the possible formation of a dilatant zone (i.e., rock dilation) was recognized (DOE, 1980a). It was assumed that the salt deposits within the Salado Formation would behave as an isotropic, homogeneous material and that the underground excavation could be maintained with only minimal activities to control fracturing.

Following excavation of the underground workings in 1982, in situ experiments were initiated to evaluate the response of the salt to excavation. Morgan et al. (1986) showed that the rate of closure measured in the underground workings was at least three times greater than predicted before access underground. Numerous holes drilled from the underground workings revealed a zone of fractures around the excavations, indicating the presence of a DRZ. As the DRZ became evident, numerous additional drillholes were advanced and observations of these drillholes indicated that fractures greater than 0.08 inches were common (Bechtel, 1986). The existence of the DRZ has been further confirmed by geophysical surveys and gas flow tests (Appendix E.8). These data indicate that the DRZ extends laterally throughout the excavation and extends outward 3-15 ft from the underground openings.

The fractures that have been observed in the DRZ, especially in the anhydrites of Marker Bed 139, can potentially provide an interconnected path of transport. These zones of fracturing may persist beyond that time when salt closure around the backfilled repository occurs. Consequently, the presence of a DRZ may provide conduits for fluids or gases originating in the formation and the waste or may provide a sink for these fluids.

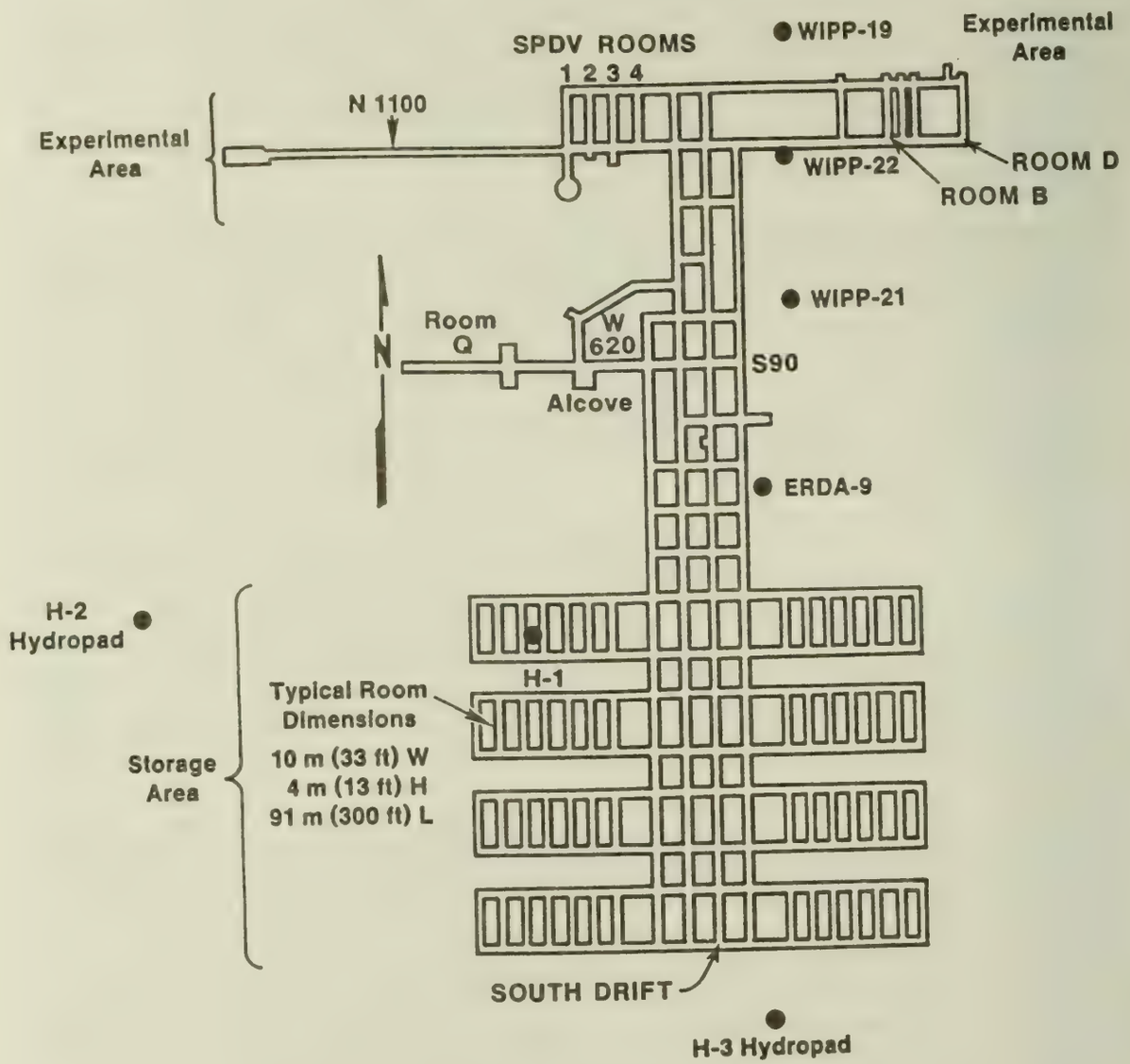
Fracture Observations at WIPP. In 1983, an exploratory drift, E140 (also known as the south drift, Figure 4.9a), was driven a distance of 1,000 m south of the site center to verify the stratigraphic continuity and suitability of the WIPP waste panel area. Following completion of the south drift, a fracture separation was observed consistently 10-15 cm up into the back of the drift (Borns & Stormont, 1988). This separation occurred within a massive halite unit and was not associated with clay seams. The separation appears to be related to a marked change in halite grain size. In response to this separation, the rock salt has been scaled and rock-bolted in portions of the south drift as a mitigation measure.

In the autumn of 1984, based in part on a recommendation by the EEG, the structures of Marker Bed 139 (MB139) (see Figure 4.9b) were studied via several drillholes in the north end of Room 4 of the SPDV (see Figure 4.9a) (Borns, 1985). These studies showed that MB139 contained fractures and that many of these fractures probably existed prior to excavation. It was also determined that these fractures provided zones of weakness that reopened in response to underground mining. During this study, several 36-inch diameter drillholes were completed in the south end of Room 4. Following advancement of these drillholes, fractures developed in the halite above the marker bed and within MB139.

In the summer and autumn of 1985, a set of 22 drillholes, 36 inches in diameter, were drilled in the south end of Room 3 (Figure 4.9a) to provide the foundations for bulkheads (Room 3 has been divided in two, with the south end becoming Room T). Following completion of these drillholes, fractures were exposed in MB139 and the overlying halite. The fracture system exposed in Room 3 was much more developed than in Room 4, with fracture separations greater than 4 inches. The drillholes in Room 3 were found to be interconnected by the fracture system. Exploratory drilling in the north end of Room 3 revealed that the fracture system extended throughout the room.

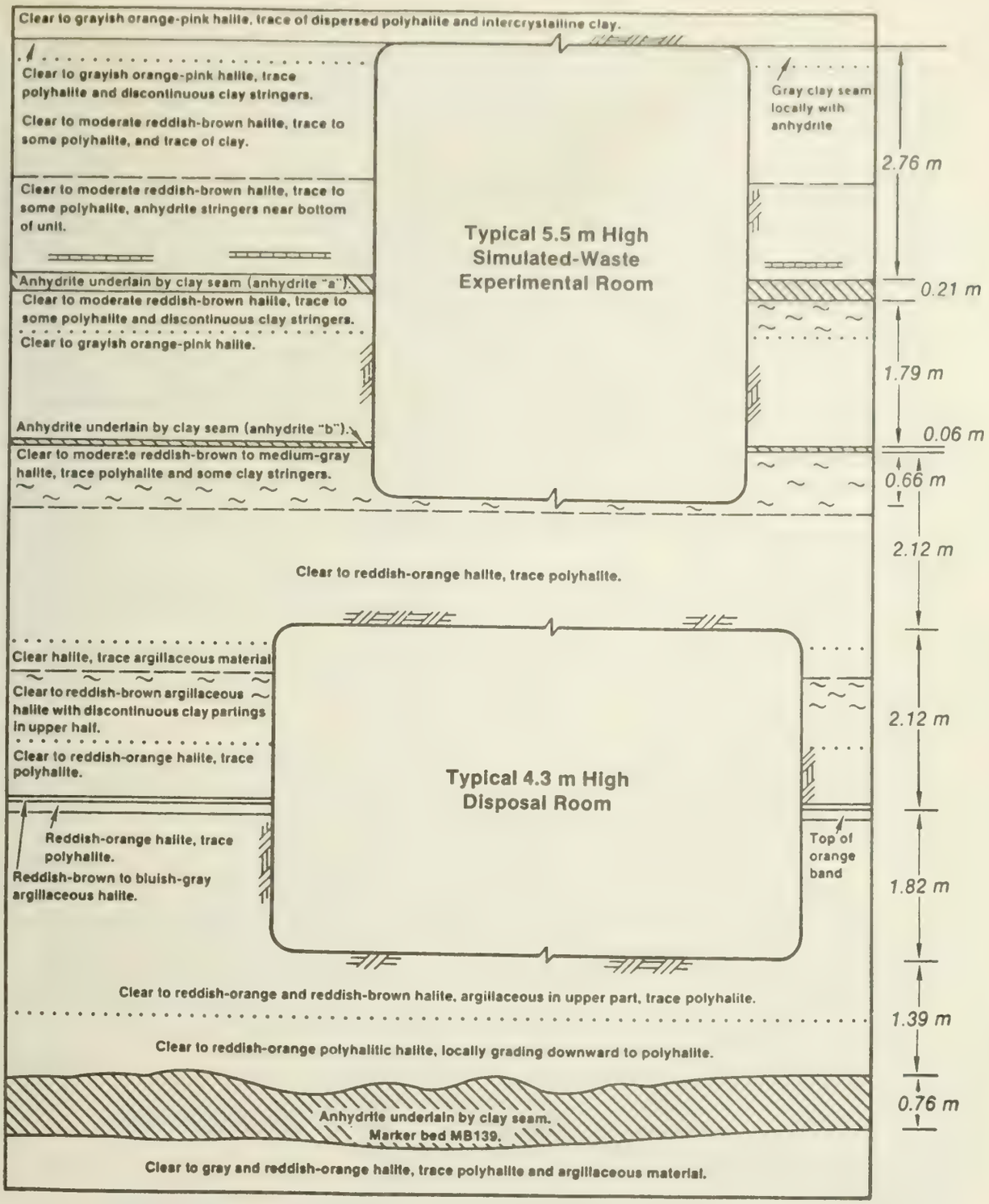
In 1986, following documentation of the fracture systems in the SPDV rooms, Bechtel National (1986) performed a reconnaissance drilling project throughout the excavations to gather more information for design validation. This study found areas of fracturing in the floor and back outside the SPDV rooms, notably in the shaft stations.

In 1987, Sandia National Laboratories began an evaluation of the backs of Test Rooms B and D (Figure 4.9a) to determine if they could support hoist equipment. This study found areally-extensive separations in both rooms; these separations required rock-bolts. Even with these measures, the roof slabs continued to fracture and were judged to be unstable in July 1987. Similar fractures and separations were expected to develop throughout the facility with time, and, in fact, rockfalls had occurred in Room 2 (Patrick, 1987). The rockfalls occurred along the west rib of Room 2, where several square feet of the roof fell. At this time, an Openings Maintenance Program was started to establish criteria and methods for control of these fractures and related features. As part of this maintenance program, strategies were developed to maintain tolerances in tramways and the waste acceptance room, and split-anchor rockbolting techniques were established to deal with the failure of resin-seated rockbolts previously used at the WIPP. Room 2 was closed because of separations in the room back. At this time, it was recommended that the first waste panel be pattern bolted to maintain



REF: LAPPIN et al., 1990.

FIGURE 4.9a
APPROXIMATE LAYOUT OF THE WIPP, SHOWING BOTH EXPERIMENTAL (NORTHERN) AND WASTE-EMPLACEMENT (SOUTHERN) PORTIONS OF THE UNDERGROUND WORKINGS



REF: LAPPIN et al., 1989.

FIGURE 4.9b
RELATIONSHIP OF MB139 TO REPOSITORY LEVEL STRATIGRAPHIC SEQUENCE

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the opening. Also, it was clear that there was a need to maintain the operational clearances in areas such as the tramways, requiring periodic trimming and rock bolting to stabilize the back. The results of an Excavation Effects Study, which described how the extent of fracturing had increased since 1986, were published in DOE (1988d).

Results of these studies indicate that this fracturing is an inherent part of room closure. It is an operational issue, a short-term concern for personnel safety. Scaling down loose rock from the back and rock bolting must continue as long as people are working underground. In the long term, rockfalls from the back and ribs are part of the process that would crush the waste containers and surrounding backfill, eventually forming a well-compacted waste mass. Tunnel closure processes and the resulting inherent uncertainties in the waste and seal permeabilities would continue to be subjects for study during the WIPP Test Phase.

Assumptions Regarding the Disturbed Rock Zone. Lappin et al. (1989) provided a description of the DRZ and developed a number of assumptions regarding the properties of the DRZ for the purposes of closure calculations. These assumptions provided a conceptual characterization of the DRZ and included the assumptions that:

- Steady-state structural and hydrologic conditions exist within the repository.
- Closure times and the resulting "final state" can be accounted for by non-dilatant (no fractures or microfractures) closure mechanisms.
- With the exception of anhydrite, rock around the excavation within the DRZ will return to its original in situ properties (strength, porosity, and permeability).
- Anhydrite can be effectively sealed with a grout whose composition and design would be determined using data obtained during the Test Phase. To analyze the consequences if this assumption is not valid, a Case IC has been added to the scenarios to estimate long-term performance of the repository (see Subsection 5.4). Case IC examines the effects of near-failure of plugs and seals and degraded transport properties on undisturbed performance. It considers the possibility that the resultant permeability of the Marker Bed 139 seals (at 4×10^{-16} m^2) will be several orders of magnitude greater than the MB139 permeabilities expected in sealing the DRZ (4×10^{-19} m^2). As a point of reference, the log mean of measured values of permeability within the disturbed portion of MB139 is 10^{-17} m^2.
- Final room configuration is not influenced by the extent or mode of rock-mass failure, such as roof collapse and rib spalling. Lappin et al. (1989), however, recognized that the DRZ might alter the time at which steady state was reached.

The assumptions made by Lappin et al. (1990) concerning the DRZ are compared to the present characterization of DRZ behavior in Table 4.7. The implications of the assumptions used to model the closure characteristics, in light of the known

TABLE 4.7 DRZ assumptions used in Lappin et al. (1990) for closure modeling versus known characteristics

Assumption	Known Characteristics
Closure mechanism has no dilatant component	Borns and Stormont (1988, 1989) demonstrated that dilatancy can account for a significant portion of the observed closure, especially at early times. Lappin et al. (1990) neglected dilatancy to simplify calculations.
Rock within DRZ will regain in situ properties with time	Assumption of rock healing simplifies long-term or steady-state calculations. Rock will approach in situ properties with time, but the extent and rate of approach have not been demonstrated. Future studies will be needed to demonstrate the degree of closure. Laboratory studies of permeability of fractured and healed specimens (Sutherland and Cave, 1978; Holcomb and Shields, 1987; Case et al., 1987) used gas injection to measure permeabilities. At lower porosities, if the rock is partially saturated or saturated, this method for determining permeability probably is not applicable. Other studies have used elevated temperatures and pressures relative to the WIPP underground conditions to facilitate healing of the rock (Costin and Wawersik, 1980). The one sample tested in Costin and Wawersik's study at repository conditions did not heal (regain strength). Studies have not yet dealt with the effects of fluids, gas, or liquid in the fractures and microfractures of the DRZ. These fluids, if contained, would eventually lower the effective stress and, thus, maintain fracture openings.
Sealing of Marker Bed 139 effective to within three orders of magnitude of host rock properties	This assumption depends greatly on the effectiveness of the composite seal-backfill-formation grout system and the time-dependent deformation around a rigid seal component. Extensive research is underway on seal material selection and design and small-scale testing of seal systems (Bertram-Howery and Hunter, 1989). Final design and materials are not yet determined. Grout designs must accommodate deformations around composite seals. Recent studies suggest that far-field anhydrite may have permeabilities one to three orders of magnitude higher than the host salt, as a result of the natural presence of fractures. Hence, it may not be possible to seal MB139 to better

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TABLE 4.7 Concluded

Assumption	Known Characteristics
	than a permeability of about 10^{-16} m^2, four orders of magnitude higher than the host salt (10^{-22} to 10^{-20} m^2). The consequences of so high a permeability are examined in Case IC; see Subsection 5.4.2.5 .
Final room configuration not affected by closure mechanism	Previous models did not incorporate DRZ effects, in part because final decisions on backfill and rock bolting have not been made. DRZ effects cannot be modeled efficiently by current methods, but the effects may be significant. For example, SPDV Rooms 1 and 2 show that roof failure can occur. Because the DOE does not expect to rock bolt panels other than Panel 1, roof failure and possibly rib spalling is expected in a decommissioned room. It is not well understood how this affects room models in detail (e.g., timing of drum breach and intermingling of contents or the storage volumes created for gas). Finally, effects of fluid-filled fractures on closure mechanisms and rates are not understood; the presence of fluids may accelerate closure while maintaining fracture openings.

characteristics, are that simulated structural room-closure times may be underestimated somewhat. Also, the DRZ, including MB139, may, under some conditions, form a relatively higher permeability pathway around emplaced seals.

Fracture Evaluation and Hydrologic Effects of the DRZ. During the development of the underground workings at the WIPP, numerous holes have been drilled specifically to investigate the DRZ (Bechtel National, 1986). The history of these observations is presented in the previous subsection. The development of a DRZ has been confirmed by geophysical surveys, gas-flow tests, and borehole observations (DOE, 1988d; Borns and Stormont, 1988). The three approaches have defined a DRZ extending laterally and vertically throughout the excavation and varying in extent from 3-15 ft. The detailed results of the gas-flow tests and geophysical surveys are presented in Appendix E.

The basic features observed include the following:

- An arcuate (i.e., arc-like) fracture system, concave toward the opening, develops in the floor and the back, locally crosscutting the stratigraphy.
- Separations may develop along stratigraphic markers, such as clay seams, both above and below the room.
- Shear displacements are observed along fractures and separations, especially near the corners of the rooms. Fracturing may or may not be locally symmetrical about the room centerline.
- Vertical fractures and spalling are observed within the ribs.
- Desaturation has occurred to some degree.
- Microfracturing is occurring, providing a component of closure not accounted for in creep models.

Re-examination of existing boreholes showed that the extent of observed fracturing increased from 48 percent of the borehole array locations in 1986 to 73 percent in 1987. Locations without fractures are largely restricted to drifts with narrow spans (14 ft). In the oldest test rooms (SPDV rooms 1 through 4, see Figure 4.9a), 100 percent of the locations were fractured. The results of the work to date have focused on the deformation around a single room or excavation. However, recent analysis by IT Corporation (Case, 1989, personal communication cited in Lappin et al., 1989) of the SPDV room response suggests that fracture deformation may be more extensive and result from panel-scale interactions.

Observations of the rate of closure show that it can be divided into three components: 1) primary or transient creep, 2) secondary creep, and 3) tertiary creep. For the WIPP, the primary and secondary creep have been extensively studied and modeled (e.g., Munson et al., 1989), but tertiary creep has received little attention. The accelerating closure of Room 1 is an example of tertiary creep. The onset of tertiary creep may mark the point at which critical strain has been achieved, after which the rock begins to fail by fracturing. As seen in the WIPP excavations, deformation has an early transient response and progresses toward steady-state creep, but steady state may not

be an accurate assumption for long-term calculations, because tertiary creep may affect deformation near the room walls at later times.

Additional discussions regarding the nature and extent of the DRZ are presented in Lappin et al. (1989). Also, discussions regarding potential impacts caused by the presence of a DRZ on the repository and potential mitigation measures are presented in Subsections 5.4.2.4 and 6.3.1.

4.3.2.5 Marker Bed 139 Structural Studies Near the WIPP. MB139 is an anhydrite marker bed that is approximately 3 ft thick. This marker bed lies about 3 ft below the floor of the underground waste disposal area. Because of concern that the undulations noted on the top of MB139 might be the result of post-depositional deformation, a detailed study of MB139 began in 1983 (Jarolimek et al., 1983). Studies reported by Jarolimek et al. (1983) and Borns (1985), however, indicate that the undulations are depositional in origin rather than having been formed by post-depositional geologic stresses.

Observations of the floors of the oldest WIPP rooms (i.e., SPDV excavations) indicate mining-induced fracturing in the rock-salt floor material and in the underlying MB139 immediately beneath the excavations. Investigations of the long-term mechanical and fluid-flow behavior of MB139 and its potential impact on the WIPP underground facility are on-going; the following discussions and conclusions are considered preliminary.

Investigations by Borns (1985) indicate that subhorizontal fracturing, partially healed by halite and polyhalite, is characteristic of MB139 and predates the construction of the WIPP. The occurrence of partially healed fractures within the central part of MB139 is important to the fluid-flow characteristics and structural behavior of the unit. Pre-existing fractures within MB139 provide potential planes of weakness that could control or influence the mechanical response of the rock around the WIPP excavation. Underground experience at the WIPP indicates that these fractures open locally in response to excavation. Away from the influence of the WIPP excavation, the permeabilities of MB139 appear to be on the order of 1 to 3 orders of magnitude greater than that of surrounding halites (Lappin, 1988).

Mining-induced opening of fractures within MB139 may provide a potential pathway for gas or brine migration. This response to mining may require that damaged portions of MB139 be removed or grouted before seal emplacement. For additional discussion see Subsections 4.3.2.4 and 6.3.1.

4.3.2.6 Geochemical and Mineralogical Environment of the WIPP Horizon. The Salado Formation is dominated by various evaporite salts with the dominant mineral being bedded salt (NaCl) of varying purity and accessory minerals. The major accessory minerals are anhydrite ($CaSO_4$), clays, polyhalite ($K_2MgCa_2(SO_4)_4 \cdot 2H_2O$), and gypsum ($CaSO_4 \cdot 2H_2O$) (Lappin, 1988; Stein, 1985; Bodine, 1978). Stein (1985) reports that, in the vicinity of the repository, authigenic quartz (SiO_2) and magnesite ($MgCO_3$) are also present as accessory minerals. The marker beds in the salt are described as anhydrite with seams of clay (Lappin, 1988). Bodine (1978) noted that the clays within the Salado Formation are enriched in magnesium and depleted in aluminum. The magnesium enrichment probably reflects the intimate contact of the clays with brines derived from evaporating sea water, which are relatively high in magnesium (Stein and Krumhansl, 1986).

Stein and Krumhansl (1986) collected and analyzed liquids from two types of fluid inclusions as well as from seeps and floor holes within the WIPP drifts. Figure 4.10 is a plot of the ratios of sodium to chloride versus potassium to magnesium in samples of these four fluids. This figure indicates that there is compositional variability of the fluids. The figure shows the effects of various phase transformations on brine composition. In summary, the fluid inclusions belong to a different chemical population than do the fluids emanating from the walls. It was concluded that much of the brine is completely immobilized within the salt and that the free liquid that emanates from the walls is present as a fluid film along intergranular boundaries (Stein and Krumhansl, 1986). This supports the discussion in Deal and Case (1987) and in Subsection 4.3.2.1.

One of the distinguishing characteristics of these intergranular fluids is the increase in the potassium/magnesium ratio. The precipitation of either magnesite ($MgCO_3$) or magnesium-rich clays from the intergranular fluids can cause this geochemical evolution. These mineral species are present as accessory minerals within the Salado Formation.

To develop a set of reference brine concentrations, Lappin et al. (1989) compiled and critically evaluated the present data from WIPP seeps and boreholes. Table 4.8 is a list of the concentrations of the major and minor components in Brine 2 (PAB 2). The critical evaluation consisted of discarding outlier values and analyses that indicated potential contamination.

4.3.3 Rustler Formation

Much effort during WIPP site characterization has been focused on the Culebra Dolomite Member of the Rustler Formation because the Culebra is the first laterally continuous hydrologic system above the Salado Formation, and it provides the most likely potential pathway for any release from the repository to the accessible environment. However, since 1983, characterization has also focused attention on other members of the formation.

At the time of the FEIS, three water-producing units were thought to exist within the Rustler. Currently, five water-bearing units have been identified within the Rustler: 1) the lower siltstone portion of the unnamed lower member of the Rustler and the Rustler-Salado contact, 2) the Culebra Dolomite, 3) the Tamarisk claystone, 4) the Magenta Dolomite, and 5) the Forty-Niner Claystone (Figure 4.11). These water-bearing units are separated by confining beds (units that inhibit water flow) of evaporite rocks (i.e., halite, anhydrite, gypsum).

The potential for the dissolution of salts (i.e., potential development of karst topography) within the Rustler Formation has also been an identified concern. The concern has been that evaporite dissolution could play a major role in the potential lateral migration of radionuclides through the Rustler by dramatically increasing the permeability in the formation through the development of karstic type fractures. In Nash Draw, 8 km (5 mi) to the west of the WIPP site, all halite has been removed from the Rustler by dissolution. In contrast, to the east of the site, the Forty-Niner, Tamarisk, and

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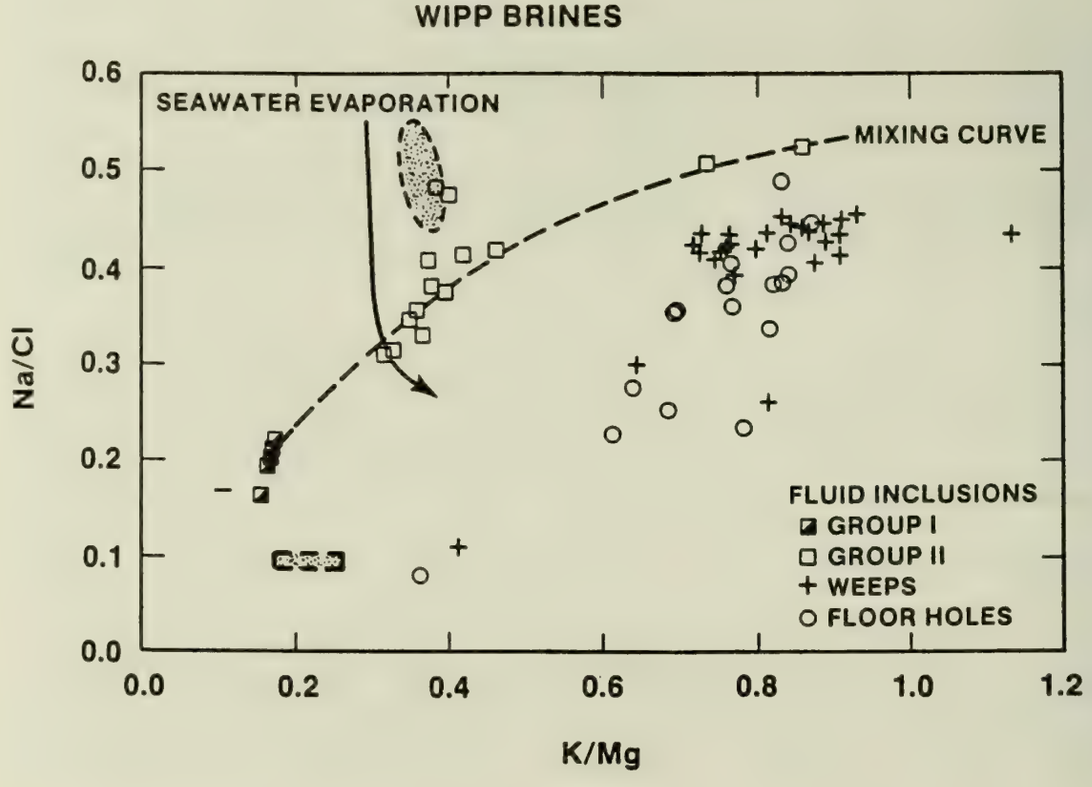


NOTE: FROM FLUID INCLUSIONS AND MACROSCOPIC BRINE OCCURENCES IN THE WIPP FACILITY; EFFECTS OF INDIVIDUAL REACTIONS ON FLUID COMPOSITION ARE ALSO INDICATED.

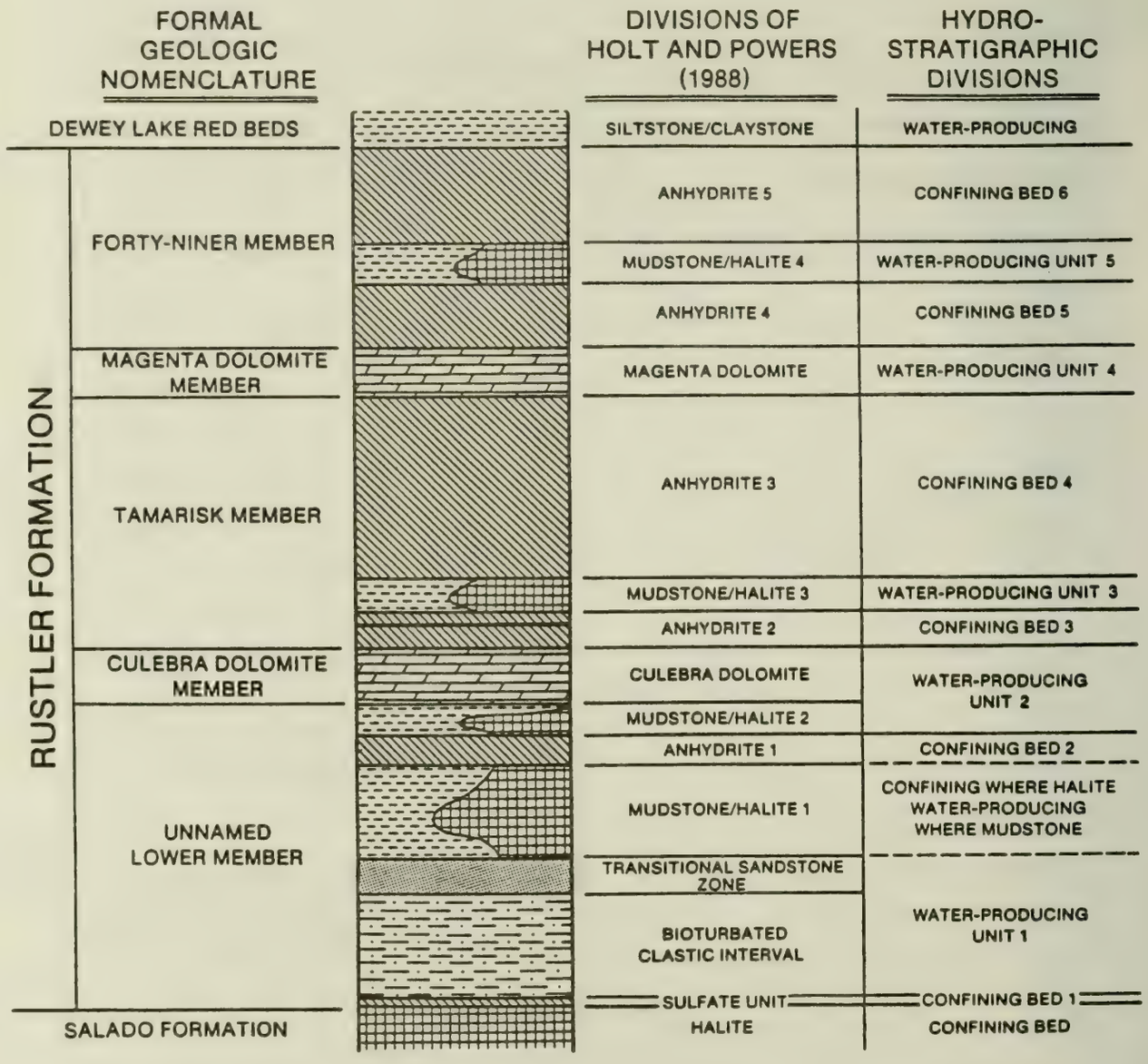
REF: STEIN AND KRUMHANSL, 1986.

FIGURE 4.10
COMPOSITIONAL VARIABILITY OF SALADO FORMATION FLUIDS

TABLE 4.8 Geochemistry of PAB 2

Species	Average Concentration (millimoles per liter)
pH (standard units)	6.1
Alkalinity (pH 4.5)[a]	13.8 (as HCO_3^-)
Extended alkalinity (pH 2 to 3)[a]	15.7 (as HCO_3^-)
B^{3+}	148
Ca^{2+}	9
K^+	510
Mg^{2+}	1,000
Na^+	3,900
Br^-	13
Cl^-	6,020
SO_4^2	170
TDS (milligrams per liters)	3.78×10^5 (milligrams per liters)
Specific gravity	1.22

[a] Final pH after titration.



REF: LAPPIN et al., 1989.

FIGURE 4.11
HYDROSTRATIGRAPHIC COLUMN OF THE RUSTLER FORMATION IN THE VICINITY OF THE WIPP SITE

the lower member of the Rustler contain abundant halite. Barrows (1982) expressed concern that karst conditions existed at the site, and Chaturvedi and Channell (EEG-32,1985) indicated that solution conduits may exist in the shallow subsurface at the WIPP site. Phillips (1989) also expressed concern that the Rustler aquifers are karstic and opined that, because of this, flowpaths and travel times are unpredictable.

Two potential methods of dissolution have been identified: 1) strata-bound dissolution (i.e., dissolution parallel to bedding), and 2) localized dissolution from recharge. The variability of halite content and the associated thickness of the Rustler Formation has been attributed to regional-scale, strata-bound dissolution. This has been based on the assumption that rock salt was deposited with uniform thickness over a large area. It has been assumed that the Nash Draw feature is due to the dissolution of Rustler salts over the past 600,000 years. The assumption that dissolution is the main cause of the variability in the salt content within the Rustler and the growth of Nash Draw has been viewed as conservative. Even considering these conservative assumptions, it does not appear feasible for salt dissolution to extend Nash Draw to the WIPP for many tens of thousands of years (Lappin, 1988).

The alternative method for the dissolution of the Rustler Formation is localized recharge. If localized recharge of unsaturated fluids occurred to a significant degree, local evaporite dissolution within the Rustler might result. The final result of such dissolution could be the generation of a "solution hole" hydrologic system similar to the karstic hydrology of at least part of the Rustler Formation in Nash Draw. Where the Rustler Formation is exposed at the surface, it is characterized by the continuing formation of small caves and sinkholes in the anhydrites of the Forty-Niner and Tamarisk Members.

The characterization of the Rustler Formation since the FEIS has provided considerable evidence regarding the potential for dissolution at the WIPP. Hydrologic measurements, including regional-scale pumping tests, have been used to evaluate the present distribution of hydraulic properties and relative head potentials (water pressures) within the Rustler at and near the WIPP. Water isotope studies have been used to estimate the relative importance of vertical fluid flow within the Rustler and Dewey Lake, and the extent to which the Rustler flow system is in a transient state.

The results of these studies indicate that vertical recharge to the Rustler is not active at the WIPP. The results of regional-scale pumping tests in the Culebra Dolomite have not identified zones of high transmissivities characteristic of dissolution features (pumping-test results are discussed later in this subsection). Also, data on the isotopes present in the water (Lambert and Harvey, 1987) indicate that the water currently present in the Rustler originated not from contemporary recharge, but from recharge that occurred during the last pluvial event (10,000 to 20,000 years before the present). It should be noted that the interpretations of Lambert and Harvey (1987) and also Lambert (1987) are not in agreement with some of the conclusions arrived at by Chapman in EEG-35, 1986. The disagreement is focused on distinctions between waters from the unconfined portions of the Capitan limestone, modern precipitation, and from the Rustler Formation at and near the WIPP site. Lambert and Harvey's response to Chapman as summarized in Lappin (1988) is presented below.

> The disagreement between the interpretations contained in Lambert and Harvey (1987) and Chapman (1986) concerning the overall nature of the hydrology in

southeastern New Mexico is fundamental, and cannot be resolved by stable-isotope studies alone. However, these studies do clarify the differences in opinion. Chapman (1986), in effect, assumes that the hydrology of southeastern New Mexico is at steady state (or, alternately, that its response to changing climatic conditions is effectively instantaneous). Chapman assumes that the weighted mean precipitation for Roswell and the statistical correlation of Craig (1961) are significant by themselves, and demonstrates that it is possible, based on these assumptions, to generate unconfined waters from Carlsbad Caverns by evaporation. By Chapman's interpretation, the unconfined Capitan waters do not represent modern recharge. However, the field of demonstrably modern Delaware Basin recharge defined by Lambert and Harvey (1987) includes or is consistent with analyses from several other locations in addition to Carlsbad Caverns. The weighted mean precipitation used by Chapman to derive unconfined Capitan waters by evaporation is also distinct from the compositional field defined by most Rustler, Dewey Lake, and confined Capitan waters. Chapman (1986) attributes this difference to a 'seasonal or amount effect.' The operation of this effect on Rustler, Dewey Lake, and confined Capitan waters, as well as Ogallala water from the High Plains is not explained.

Lambert and Harvey (1987) do not assume that the hydrology of southeastern New Mexico is at steady state. They do assume that significant departure in isotopic signature from the meteoric field defined by the compositional space between the statistical correlations of Craig (1961) and Epstein et al. (1965, 1970) is required before any recourse to evaporation is justified. Unconfined Capitan waters (and others, such as Ogallala fluids and samples from alluvium at WIPP-15) are interpreted by Lambert and Harvey (1987) to represent modern meteoric recharge in the northern Delaware Basin. The demonstrably different isotopic character of most Rustler, Dewey Lake, and confined Capitan waters from the waters that Lambert and Harvey have interpreted to represent modern recharge in the northern Delaware Basin is taken to reflect recharge under conditions distinctly different from those controlling modern recharge. Since steady state is not assumed, no single weighted mean precipitation is either defined or deemed relevant. The conclusions of isotopic studies . . . are consistent with the interpretation of a transient hydrologic setting of the Rustler Formation and shallower units at and near the WIPP site.

4.3.3.1 Hydrogeology of the Rustler Formation Water-Bearing Units.

Unnamed Lower Member and Rustler-Salado Contact. The unnamed lower member of the Rustler Formation consists of a layered sequence of clayey siltstone, gypsum/anhydrite, and rock salt. In and near the WIPP, the thickness of the unnamed lower member ranges from 79 ft (at ERDA-6) to 151 ft (at P-18). The lower siltstone unit of the unnamed member (the transition zone and the biologically disturbed clastic interval of Holt and Powers [1988]) can be considered to be the lowermost Rustler water-producing zone, while the overlying rock salt and anhydrite/gypsum units act as another confining bed. The top unit of the unnamed member is composed of siltstone, mudstone, and claystone. At some locations south and east of the WIPP site, such as at P-18, this unit also contains rock salt (Holt and Powers, 1988).

Typically, the transmissivities of the water-producing portion of the unit vary from 10^{-11} to 10^{-9} m^2/s. Where the dissolution of the upper Salado Formation has occurred, the

transmissivities tend to be at the higher end of the range. Under these conditions, the brine-bearing residue of the upper Salado may be hydraulically continuous with the siltstone of the unnamed member.

To the west and southwest of the WIPP site, where rock salt is absent from the upper Salado Formation and the lower Rustler Formation, a more transmissive zone exists in the residue of the upper Salado Formation at the contact with the Rustler Formation. The brecciation (breaking up into angular fragments) of the unnamed lower member has been observed in Nash Draw where the upper Salado Formation has been dissolved (Holt and Powers, 1988), but the degree to which this brecciation may have caused enhanced transmissivity or decreased the effectiveness of the confining beds of the unnamed member is not clear from the available evidence. Where dissolution of the upper Salado Formation has not occurred, no significant permeability is associated with the upper Salado Formation and its contact with the Rustler Formation, and the lower siltstone provides the only water-producing unit in the lower Rustler Formation.

Very few measurements have been made of the stabilized water level or fluid pressure of the unnamed lower member of the Rustler Formation. Water levels take months to years to stabilize in wells installed in saturated sediments having extremely low transmissivity, such as those that make up the unnamed member. Most of the borings testing the lower Rustler Formation and/or upper Salado residuum were temporary measurement points and did not remain open long enough to reach hydraulic equilibrium (i.e., water-pressure conditions returning to static conditions after drilling). Hydraulic head data are believed to be reliable only at those wells where transmissivities in the unit exceed 10^{-10} m^2/s (Lappin et al., 1989).

Because the highly variable salinity of the water in the Rustler and Salado Formations affects the density of the waters and the resulting hydraulic head (water level measurement for determining pressure), the hydraulic-head data must be corrected to a common density (in this case, freshwater) to determine groundwater flow patterns. The corrected data indicate that flow through the low-transmissivity section of the Rustler-Salado contact is generally westerly or southwesterly across the WIPP site toward the sink represented by the higher transmissivities in Nash Draw. The flow within Nash Draw appears to be generally southwesterly toward Malaga Bend on the Pecos River.

Culebra Dolomite. The Culebra Dolomite Member of the Rustler Formation is a finely crystalline, locally clayey, sandy, vuggy (containing small cavities) dolomite ranging in thickness from 23 ft (at DOE-1 and other locations) to 46 ft (at H-7) in the vicinity of the WIPP (Lappin et al., 1989). Of the hydrostratigraphic units present within the Rustler Formation, the Culebra has the greatest potential of providing a groundwater-transport pathway to the accessible environment. Accordingly, much attention has been devoted to understanding the hydrogeologic and hydraulic properties of the Culebra.

The Culebra is underlain by a siltstone/mudstone/claystone unit of the unnamed lower member and overlain by an anhydrite unit of the Tamarisk Member. These units provide confining hydraulic boundaries for the Culebra. During the WIPP site characterization, regional hydraulic properties have been investigated by multipad interference testing of the Culebra Dolomite. These tests are conducted by pumping a test well over a long

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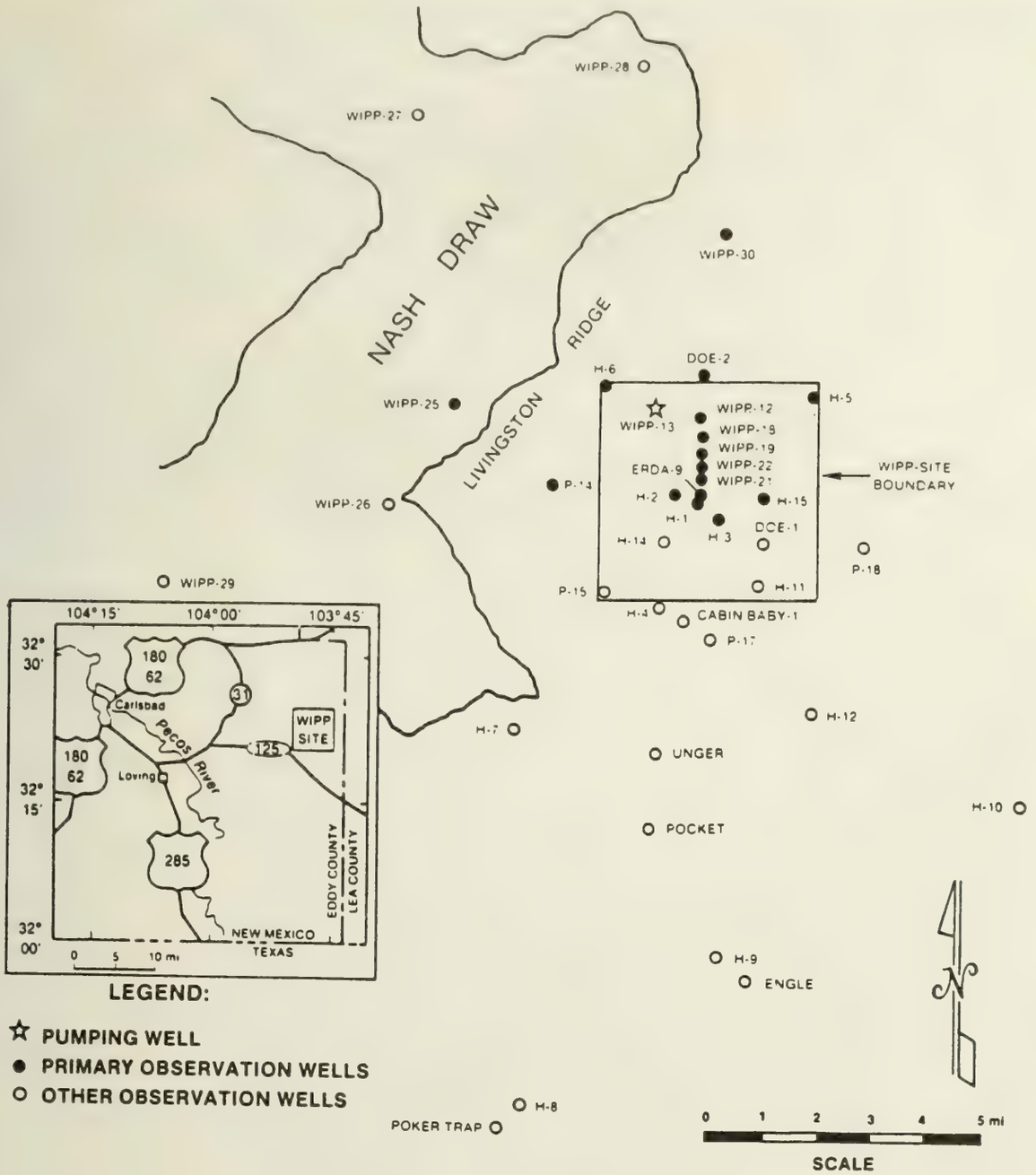
time (e.g., for a month or longer), while surrounding holes are used to observe response to stress in the Culebra Dolomite over an area of several square miles.

Three multipad interference tests have been conducted to date. These tests were conducted in the Culebra Dolomite and were centered at hydropad H-3, hole WIPP-13, and hydropad H-11. The locations of WIPP-13 and the wells used for observation are shown in Figure 4.12. The locations of the H-3 multipad and the observation wells for this test are shown in Figure 4.13. Interpretation of the H-11 multipad test has recently been completed, and is included in the present interpretation of the transmissivity distribution in the Rustler.

The pumping phase of the H-3 multipad interference test took place between October 15, 1985, and December 16, 1985. The collection of recovery data (the period when conditions return to normal) extended to April 16, 1986. The Culebra potentiometric surface (water-pressure levels) at the WIPP site is and has been affected by a small continuous discharge (0.5 to 1 gal/min per shaft) into the WIPP shafts (Haug et al., 1987). Thus, delineation of a potentiometric surface undisturbed by WIPP activities is difficult. LaVenue et al. (1988) performed a thorough review of Culebra water-level data, fluid-density data, and WIPP-related hydraulic stresses and derived estimates of the undisturbed freshwater heads at 31 wells. These estimates are shown contoured on Figure 4.14. The freshwater-head contours indicate a southerly flow direction across the WIPP site, a southwesterly flow direction down Nash Draw, and an area of low gradients with apparent westerly flow south of the WIPP site. Lappin et al. (1989) report that flow directions in this southern area of low hydraulic gradients are difficult to define reliably because variations in fluid density in this part of the Culebra may be as important as head differences in determining flow directions.

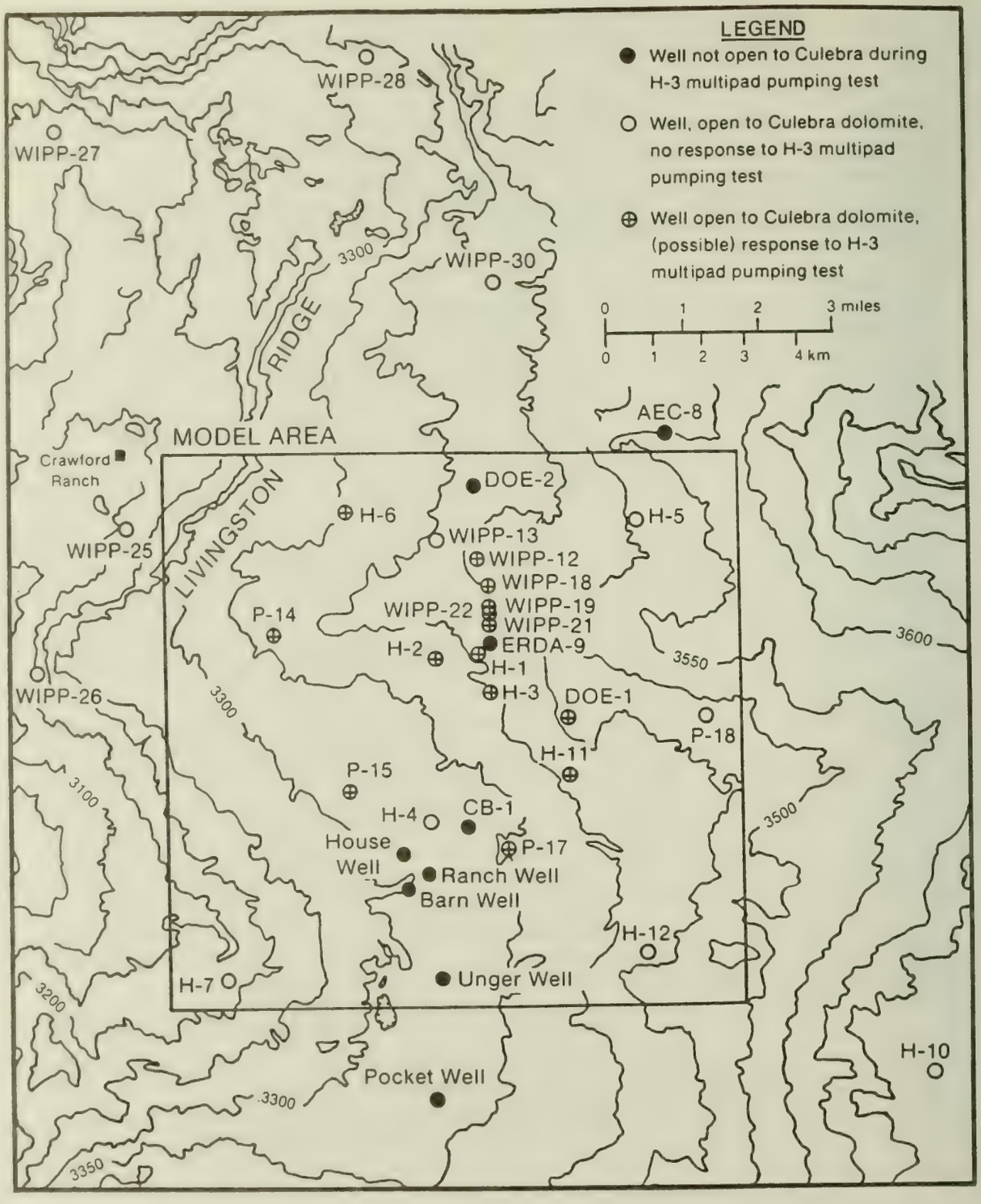
Tamarisk Claystone. The Tamarisk Member of the Rustler Formation is composed of two anhydrite and/or gypsum units with a silty mudstone interbed in the lower half of the member (Figure 4.11). The anhydrite/gypsum units act as confining beds, while the mudstone is the least productive of the Rustler water-producing units. Less is known about the hydraulic properties of the Tamarisk than about those of the other Rustler members. Hydraulic tests of the Tamarisk claystone have been attempted at only four locations: H-3b3 (unpublished field notes, 1984), DOE-2 (Beauheim, 1986), H-14 (Beauheim, 1987a), and H-16 (Beauheim, 1987a). Testing at all four locations was inconclusive, apparently because the transmissivities were too low to measure over a period of several days. Similar tests performed successfully on the unnamed lower member at H-16 (Beauheim, 1987a) indicate that the transmissivity of the Tamarisk claystone is likely 10^{-11} m^2/s or less in the vicinity of the WIPP.

Magenta Dolomite. The Magenta Dolomite Member of the Rustler Formation is a sandy dolomite containing gypsum. It ranges in thickness from 16 ft (at WIPP-27) to 30 ft (at H-9) in the vicinity of the WIPP. The Magenta is absent at WIPP-29 and is unsaturated at H-7a and WIPP-26 (Mercer, 1983).



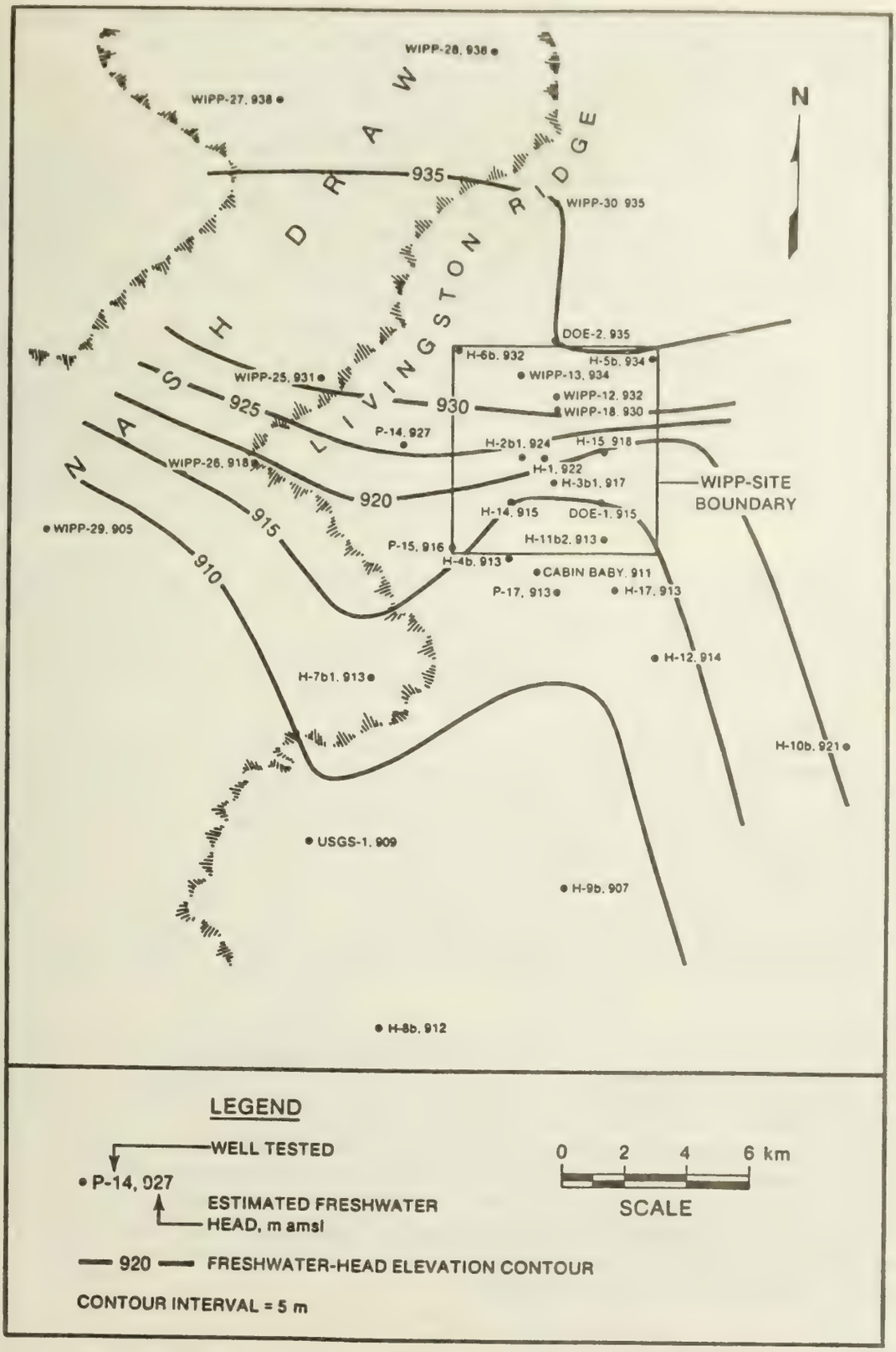
REF: BEAUHEIM, 1987c.

FIGURE 4.12
PUMPING AND OBSERVATION WELLS FOR THE WIPP-13 MULTIPAD INTERFERENCE TEST



REF: HAUG et al., 1987.

FIGURE 4.13
PUMPING AND OBSERVATION WELLS FOR THE H-3 MULTIPAD INTERFERENCE TEST



REF: LAPPIN et al., 1989.

FIGURE 4.14
ESTIMATED FRESHWATER HEADS OF THE CULEBRA DOLOMITE MEMBER

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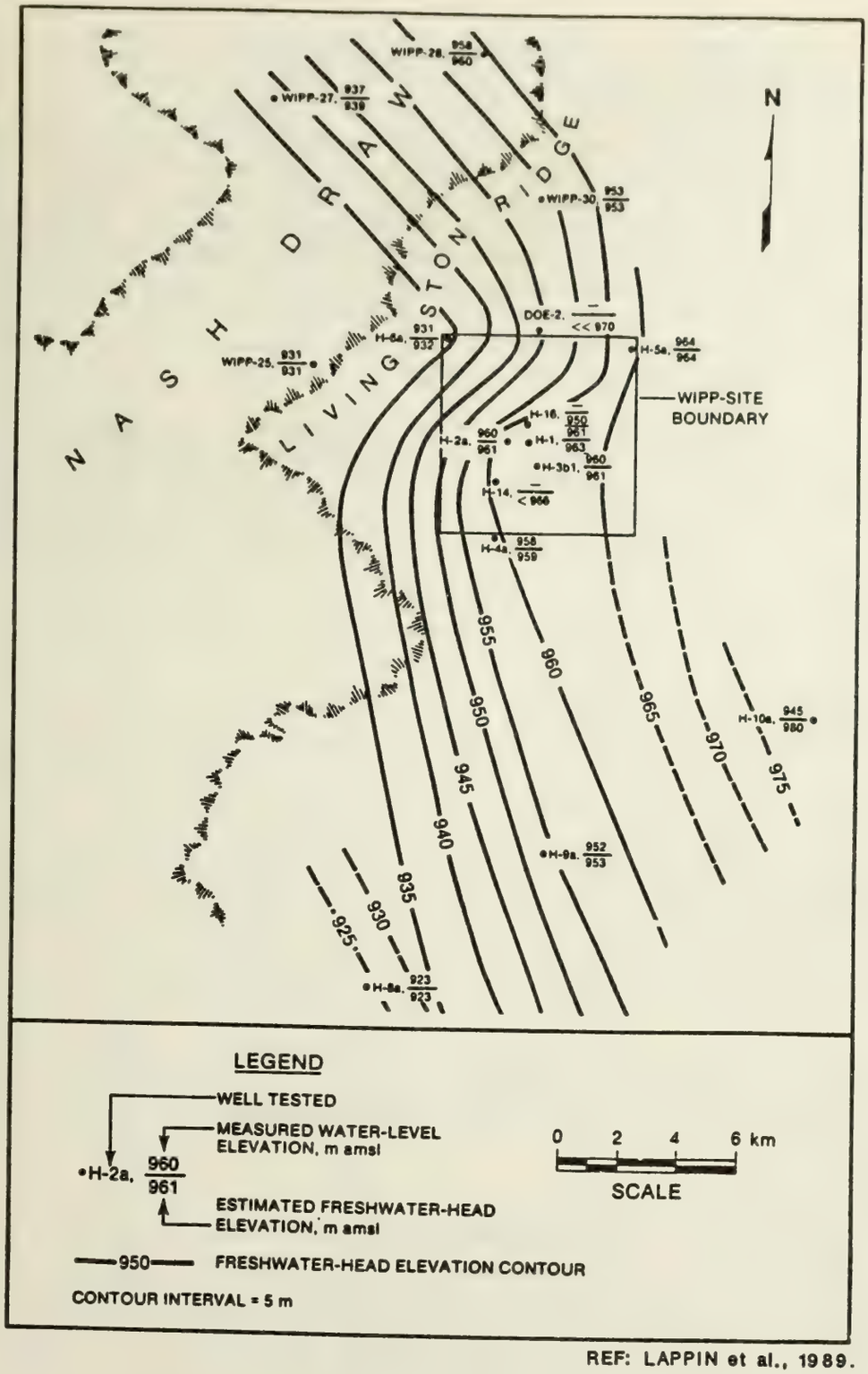
Hydraulic tests have been performed on the Magenta Dolomite at 16 locations (Mercer, 1983; Beauheim, 1986, 1987a). Most of the transmissivity values are less than or equal to 10^{-7} m^2/s. Relatively high values of transmissivity, 3×10^{-7} and 1×10^{-6} m^2/s, are found at H-6a and H-9a, respectively. Rock salt is not present in the Rustler Formation at either of these two locations, and transmissivities measured within the Culebra are also high at both locations. The two highest values of Magenta transmissivity, 4×10^{-4} and 6×10^{-5} m^2/s, are found in Nash Draw at WIPP-25 and WIPP-27, respectively, where dissolution in the upper Salado has caused the collapse and fracturing of the overlying Rustler. Dissolution in the upper Salado has apparently not affected the Magenta at all locations where the Salado has dissolved; for example, the transmissivity of the Magenta is very low at H-8 and could not be measured at WIPP-28.

Stabilized hydraulic-head data were measured in the Magenta between 1979 and 1981 (Richey, 1987b). Density-corrected hydraulic-head estimates calculated from specific-gravity or fluid-density data presented by Mercer et al. (1987), Dennehy and Mercer (1982), Mercer (1983), Lambert and Robinson (1984), Richey (1986), and Richey (1987a) and measured heads are shown in Figure 4.15. The contours, based on corrected data, indicate a generally westwardly flow direction across the WIPP and a southwesterly flow direction within the Magenta in the northern portion of the Nash Draw.

Forty-Niner Member. The Forty-Niner Member of the Rustler Formation is composed of two anhydrite and/or gypsum units separated by a silty mudstone interbed. The anhydrite/gypsum units act as confining beds to the saturated mudstone interbed. In the vicinity of the WIPP, the thickness of the Forty-Niner ranges from 23 ft at WIPP-27 to 75 ft at P-18. The Forty-Niner is entirely absent at WIPP-29 (Mercer, 1983).

The mudstone interbed of the Forty-Niner has been hydraulically tested at only three locations: DOE-2, H-14, and H-16 (Beauheim, 1986; 1987a). At these locations, the thickness of the interbed ranges from 10 to 16 ft. The transmissivities reported for the mudstone interbed at these locations range from 10^{-9} to 10^{-7} m^2/s. Although no direct measurements have been made, it is assumed that transmissivities may be higher west of the WIPP site in Nash Draw, as is the case with the other Rustler members. Measurements of the hydraulic head of the Forty-Niner mudstone have been made at wells H-3d, H-14, H-16, and DOE-2 (Beauheim, 1987a). These data are not inconsistent with a flow system that is southwesterly, which is generally consistent with other members in the Rustler Formation.

Hydraulic-Head Relations. The hydraulic-head distributions shown for the unnamed lower member of the Rustler Formation and the Rustler/Salado contact, the Magenta Dolomite Member, and the Forty-Niner mudstone all indicate westerly to southwesterly components to the groundwater flow in these units. Flow in the generally more transmissive Culebra appears to be largely southerly. Steady-state flow conditions would indicate that recharge to the Rustler Formation is to the east or northeast of the WIPP. However, to the east of the WIPP, the depth at which the Rustler is located increases, the transmissivities of the water-producing units decrease, and the thickness and effectiveness of confining beds increase. All of these factors argue against the existence of recharge areas to the east.



REF: LAPPIN et al., 1989.

FIGURE 4.15
WATER LEVELS AND ESTIMATED FRESHWATER HEADS IN THE MAGENTA DOLOMITE MEMBER

Data on the isotopes in the Rustler groundwaters and hydraulic-head distributions in the Rustler Formation (Lambert and Harvey, 1987) indicate that the flow systems are not at steady state, but are instead in a transient state following a major recharge event during the latest pluvial period. The Rustler Formation was recharged, perhaps from the present vicinity of Nash Draw, during a pluvial period approximately 10,000 to 20,000 years before the present. Following the climatic change to the current semi-arid conditions, the Rustler began to drain to the west or southwest. The Culebra, the most transmissive of the Rustler water-producing units, apparently has drained more quickly than the other units, resulting in its present-day flow direction. Numerical simulation (Lappin et al., 1989) of the recharge-discharge scenario proposed by Lambert and Harvey (1987) indicates that the current distribution of heads is a plausible result of more than 10,000 years of drainage from the Rustler.

4.3.3.2 Hydrologic Testing of the Rustler Formation. The Rustler Formation hydrogeologic data base at the time of the FEIS consisted of data derived from testing at eight locations (Cooper and Glanzman, 1971; Mercer and Orr, 1979). The WIPP site characterization of the Rustler Formation that has taken place since the FEIS has included testing at 33 additional well sites. Hydrologic testing of the Rustler Formation has occurred at three geometric scales: 1) local or point tests in single holes; 2) multiple-well hydropad (three wells at 98.4-ft or other spacing, in the form of an equilateral triangle) tests; and 3) regional-scale testing using multiple hydropads.

Single-Hole Tests. Single-hole hydrologic testing has provided 1) local transmissivity values for all members of the Rustler Formation except the Tamarisk, with focus on the Culebra; 2) indications of local fracturing and well-bore damage in the Culebra; 3) relative head data within the Rustler; and 4) some indication of the hydraulic properties and degree of saturation in the Dewey Lake Red Beds (Lappin, 1988). Single-hole testing methods are discussed by Beauheim (1987b). Tests were conducted by means of pumping, drillstem, slug-injection, slug-withdrawal, or pressure-pulse methods. Results of the single-well tests discussed in Barr et al. (1983), Haug et al. (1987), LaVenue et al. (1988), and Beauheim (1986, 1987b) are presented in Tables 4.9 and 4.10. Single-well tests provide only a localized measure of hydraulic properties at the point of the test. They do not indicate the extent to which transmissivity values or fracturing effects can be extrapolated laterally.

Single-Pad, Multiple-Well Hydropad Tests. In order to provide a more laterally extensive understanding of the Culebra hydraulic properties, tests were conducted on a hydropad scale. During testing, a single well is pumped and the other two wells provide observation points.

Single-hydropad tests have been completed at the H-2, H-3, H-4, H-5, H-6, H-7, H-9, and H-11 hydropads. The locations of these hydropads and the wells used as observation points for the large-scale multipad interference tests are shown in Figure 4.16. Detailed evaluations have been completed only for the tests conducted at H-3 and H-11. Test interpretation methods and details of analysis are discussed by Saulnier (1987) and Beauheim (1987a), and the results are summarized by Lappin (1988) and in Table 4-11. The interpretation of the test data made use of a dual-porosity approach, that is, a method that takes into account both the primary matrix porosity and the secondary porosity created by fracturing.

TABLE 4.9 Transmissivity data bases used in the numerical modeling of the Culebra Dolomite by Barr et al. (1983), Haug et al. (1987), and LaVenue et al. (1988)

Well	Transmissivity (ft^2/day)			
	Barr et al. (1983)	Haug et al. (1987)	LaVenue et al. (1988)	Average transmissivity (m^2/s)
H-1	0.07	0.07	0.8	8.60×10^{-7}
H-2	0.4	0.56	0.52	5.59×10^{-7}
H-3	19	3.7	2.3	2.47×10^{-6}
H-4	0.9	1.1	0.95	1.02×10^{-6}
H-5	0.2	0.16	0.14	1.51×10^{-7}
H-6	73	74	74	7.96×19^{-5}
H-7	>1000	1120	1030	1.11×10^{-3}
H-8	16	6.7	8.2	8.82×10^{-6}
H-9	230	170	160	1.72×10^{-4}
H-10	0.07	0.07	0.07	7.53×10^{-8}
H-11	--	10	26	2.80×10^{-5}
H-12	--	0.04	0.18	1.94×10^{-7}
H-14	--	--	0.31	3.33×10^{-7}
H-15	--	--	0.12	1.29×10^{-7}
H-16	--	--	0.7	7.53×10^{-7}
H-17	--	--	0.2	2.15×10^{-7}
H-18	--	--	--	--
WIPP-12	--	--	0.03	3.23×10^{-8}
WIPP-13	--	--	69	7.42×10^{-5}
WIPP-18	--	--	0.3	3.23×10^{-7}
WIPP-19	--	--	0.6	6.45×10^{-7}
WIPP-21	--	--	0.25	2.69×10^{-7}
WIPP-22	--	--	0.37	3.98×10^{-7}
WIPP-25	270	270	270	2.90×10^{-4}
WIPP-26	1250	1250	1250	1.34×10^{-3}
WIPP-27	650	650	650	6.99×10^{-4}
WIPP-28	18	18	18	1.94×10^{-5}
WIPP-29	1000	1000	1000	1.08×10^{-3}
WIPP-30	0.3	0.3	0.3	3.22×10^{-7}
P-14	140	233	214	2.30×10^{-4}
P-15	0.07	0.08	0.09	9.68×10^{-8}
P-17	1	1.7	1.3	1.40×10^{-6}
P-18	0.001	0.002	0.002	2.15×10^{-9}
DOE-1	--	33	11	1.18×10^{-6}
DOE-2	--	36	89	9.57×10^{-6}
ERDA-9	--	--	0.47	5.06×10^{-7}
CABIN BABY-1	--	--	0.28	3.01×10^{-7}
ENGLE	--	--	43	4.62×10^{-5}
USGS-1	515	515	515	5.54×10^{-4}
	21 values	25 values	38 values	38 values

TABLE 4.10 Detailed summary of the results of recent single-well tests in the Culebra Dolomite (Beauheim, 1987b)[a]

Well	Culebra interval m (ft)	Interval tested m (ft)[b]	Test type	Transmissivity ft^2/day	Transmissivity m^2/s
H-1	206-213.1 (676-699)	205.7-214.3 (675-703)	Slug 1	1.0	1.1×10^{-6}
			Slug 2	0.83	8.9×10^{-7}
			Slug 3	0.83	8.9×10^{-7}
			Slug 4	0.83	8.9×10^{-7}
H-4c	149.4-157.3 (409-516)	150.6-158.5 (494-520)	Slug	0.65	7.0×10^{-7}
H-8b	179.2-187.1 (588-614)	175.0-190.2 (574-624)	Pumping	8.2	8.8×10^{-6}
H-12	250.9-259.1 (823-850)	249.9-271.3 (820-890)	Slug	0.18	1.9×10^{-7}
H-14	155.1-174.3 (545-572)	162.5-167.9 (533-550.7)	Drillstem	0.096	1.0×10^{-7}
			Drillstem	0.10	1.1×10^{-7}
			Drillstem	0.10	1.1×10^{-7}
H-14	166.1-174.3 (545-572)	162.5-175.0 (533-574)	Drillstem	0.30	3.2×10^{-7}
			Drillstem	0.31	3.3×10^{-7}
			Slug	0.30	3.2×10^{-7}
H-15	262.4-269.1 (861-883)	260.0-271.3 (853-890)	Drillstem	0.15	1.6×10^{-7}
			Drillstem	0.15	1.6×10^{-7}
			Slug	0.10	1.1×10^{-7}
H-16	213.4-221.0 (700-725)	212.4-223.7 (697-734)	Drillstem	0.85	9.1×10^{-7}
			Drillstem	0.85	9.1×10^{-7}
			Slug	0.69	4.7×10^{-7}
H-17	215.2-222.8 (706-731)	214.3-224.0 (703-735)	Drillstem	0.21	2.3×10^{-7}
			Drillstem	0.22	2.4×10^{-7}
			Slug	0.22	2.4×10^{-7}
H-18	210.3-217.3 (690-713)	208.8-217.6 (685-714)	Drillstem	2.2	2.4×10^{-6}
			Drillstem	2.2	2.4×10^{-6}
			Slug	1.7	1.8×10^{-6}
WIPP-12	246.9-254.5 (810-835)	248.4-256.0 (815-840)	Slug 1	0.10	1.1×10^{-7}
			Slug 2	0.097	1.0×10^{-7}

TABLE 4.10 Concluded

Well	Culebra interval m (ft)	Interval tested m (ft)[b]	Test Type	Transmissivity ft^2/day	Transmissivity m^2/s
WIPP-18	239.9-246.3 (787-808)	239.0-245.7 (784-806)	Slug	0.30	3.2×10^{-7}
WIPP-19	230.4-237.4 (756-779)	229.8-237.7 (754-780)	Slug	0.60	6.5×10^{-7}
WIPP-21	222.2-229.5 (729-753)	221.6-228.9 727-751)	Slug	0.25	2.7×10^{-7}
WIPP-22	226.2-232.9 (742-764)	228.0-234.7 (748-770)	Slug	0.37	4.0×10^{-7}
WIPP-30	192.3-199.0 (631-653)	191.7-199.6 (629-655)	Slug 1	0.18	1.9×10^{-7}
			Slug 2	0.17	1.8×10^{-7}
P-15	125.9-132.6 (413-435)	125.0-133.5 (410-438)	Slug 1	0.090	9.7×10^{-8}
			Slug 2	0.092	9.9×10^{-8}
P-17	170.1-177.7 (558-583)	170.1-178.6 (558-586)	Slug 1	1.0	1.1×10^{-6}
			Slug 2	1.0	1.1×10^{-6}
P-18	277.1-285.9 (909-938)	277.1-286.5 (909-940)	Slug	4.3×10^{-3}/ 7×10^{-5}[c]	4.6×10^{-9}/ 7.5×10^{-11}[c]
ERDA-9	214.6-221.6 (704-727)	214.9-221.9 (705-728)	Slug 1	0.45	4.8×10^{-7}
			Slug 2	0.47	5.1×10^{-7}
Cabin Baby-1	153.3-161.2 (503-539)	153.3-161.2 (503-529)	Slug 1	0.28	3.0×10^{-7}
			Slug 2	0.28	3.0×10^{-7}
DOE-1	250.2-256.9 (821-843)	249.9-256.9 (820-843)	Pumping and drawdown	28	3.0×10^{-5}
			recovery	11	1.2×10^{-5}
Engle	200.0-207.6 (659-681)	197.5-208.2 (648-683)	Pumping	43	4.6×10^{-5}

[a] Slightly modified from Table 5-3 of Beauheim (1987b).

[b] Actual intervals open to the wells.

[c] Interpretation of the early and late portions of the record.

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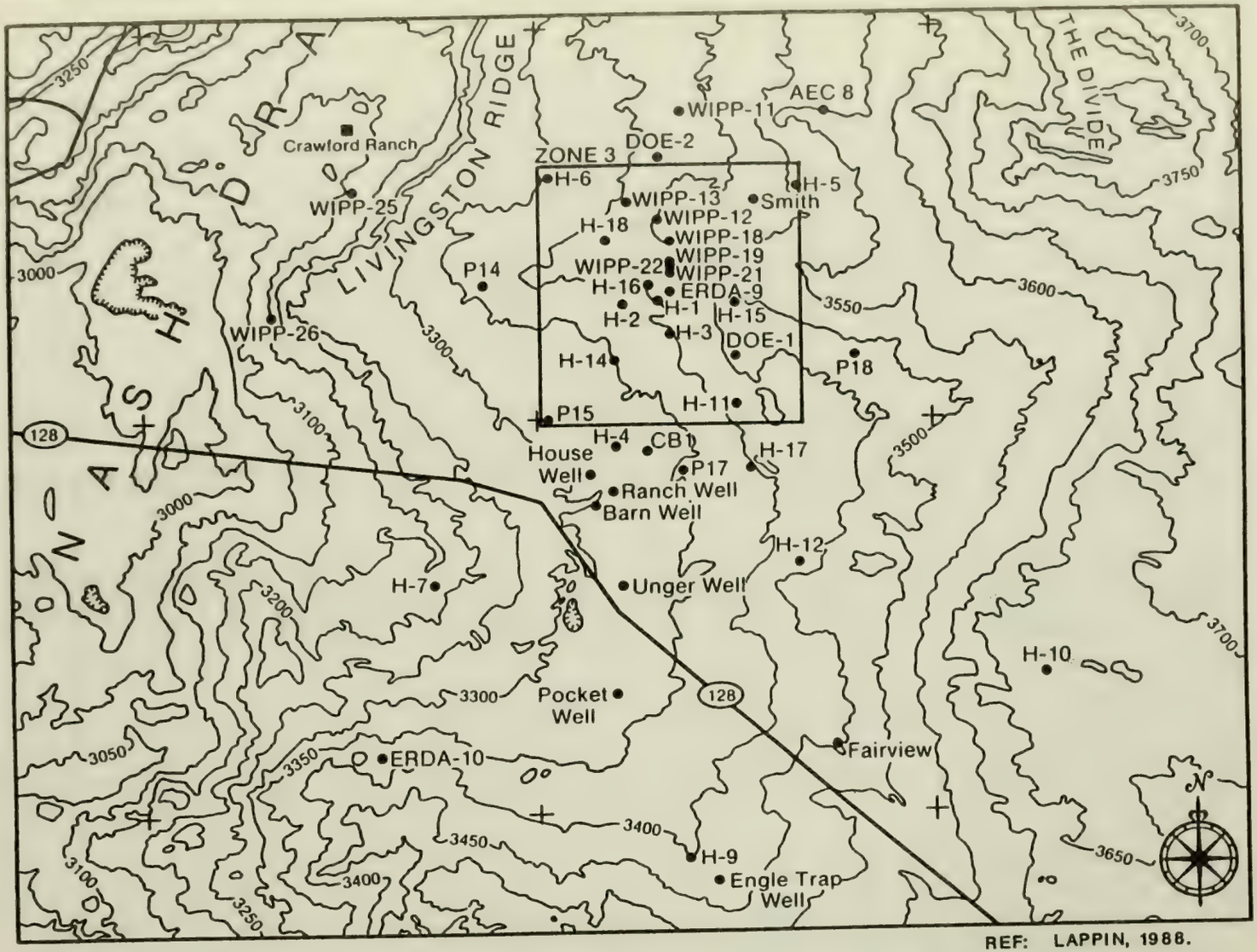

REF: LAPPIN, 1988.

NOTE: ONLY BOREHOLES WHICH HAVE BEEN HYDROLOGICALLY TESTED ARE INCLUDED.

FIGURE 4.16
BOREHOLES AT AND NEAR THE WIPP SITE

Table 4.11 Summary of the results of single-pad interference tests in the Culebra Dolomite at the H-3 and H-11 hydropads[a]

Well[b,c]	Transmissivity (m^2/s)	Skin factor	Storativity	Storativity ratio (ω)	Flow ratio (λ)
H-3[c]					
H-3b3 (1984, pump)	3.1×10^{-6}	-7.8	-----	0.07	-----
H-3b1	3.2×10^{-6}	-7.3	-----	0.25	-----
H-3b2	3.2×10^{-6}	-7.6	-----	0.04	-----
H-3b2 (1986, pump)	1.8×10^{-6}	-8.1	-----	0.03	-----
H-3b1	1.9×10^{-6}	-7.7	-----	0.25	-----
H-3b3	1.9×10^{-6}	-8.0	-----	0.10	-----
H-11b1 (1984, pump)	1.2×10^{-5}	-3.3	-----	0.01	1.3×10^{-9}
H-11b2	2.5×10^{-5}	-----	8.0×10^{-4}	0.35	2.0×10^{-6}
H-11b3	2.8×10^{-5}	-----	5.5×10^{-4}	0.35	1.3×10^{-6}
H-11b2 (1984, pump)	-----	-----	-----	-----	-----
H-11b1	2.7×10^{-5}	-----	6.1×10^{-4}	0.43	2.0×10^{-6}
H-11b3	2.6×10^{-5}	-----	4.5×10^{-4}	0.40	3.8×10^{-6}
H-11b3 (1984, pump)	2.8×10^{-5}	-4.4	-----	0.01	2.3×10^{-6}
H-11b1	2.7×10^{-5}	-----	6.3×10^{-4}	0.30	1.3×10^{-6}
H-11b2	2.6×10^{-5}	-----	7.2×10^{-4}	0.30	1.3×10^{-6}
H-11b3 (1985, pump)	3.0×10^{-5}	-4.6	2.9×10^{-3}	0.01	3.7×10^{-7}
H-11b1	2.7×10^{-5}	-----	2.9×10^{-3}	0.07	5.0×10^{-6}
H-11b2	2.8×10^{-5}	-----	2.6×10^{-3}	0.07	5.8×10^{-6}

[a] Slightly modified from data contained in Tables 6-1 and 6-3 of Beauheim (1987a) and Table 6.1 of Saulnier (1987).

[b] All wells not labeled "pump" were observation wells.

[c] All wells at the H-3 pad were interpreted as part of the pumped well; therefore, storativities are not available, but skin factors and point transmissivities are available for all wells.

Multipad Interference Tests. The results of the hydropad tests, while providing valuable information on the hydraulic characteristics of the Culebra, do not provide an understanding of the Culebra hydraulic characteristics integrated over a large scale (several square miles). The regional effects of fracturing and whether the hydrologic system can regionally be treated as a porous medium for the purposes of transport modeling could be tested only by large-scale-system hydraulic-stress investigations. Such investigations use multipad interference tests.

Three multipad interference tests have been conducted to date. These tests were conducted in the Culebra Dolomite and were centered at hydropad H-3, hole WIPP-13, and hydropad H-11.

The locations of the H-3 multipad and the observation well are shown in Figure 4.13. The pumping phase of the H-3 test took place between October 15, 1985, and December 16, 1985. The collection of recovery data extended to April 16, 1986. Evaluation of the test data included the use of analytical methods (Beauheim, 1987a) and numerical simulations (Haug et al., 1987).

The results of the analytical evaluations are presented in Table 4.12. Because of the rapid response to pumping stress at observation wells DOE-1 and H-11b1 and the relatively high calculated transmissivities (approaching 10^{-5} m^2/s), Beauheim concluded that there is a preferential connection between the H-3 pad and the southeastern portion of the WIPP site. Tomasko and Jensen (1987) noted a linear relationship of drawdown versus the square root of time between DOE-1, H-11b1, and H-3b2. This provides a strong indication of linear flow (rather than radial flow), suggesting a zone of higher transmissivity bounded by less permeable materials.

An analytical approach to the evaluation of regional-scale hydraulic properties in a system as complex as the Culebra has significant limitations. Haug et al. (1987) applied the numerical code SWIFT II (Reeves et al., 1986a; Reeves et al., 1986b) to the evaluation of regional-scale hydraulic testing of the Culebra. The numerical approach takes into consideration: 1) complex patterns of regional flow (i.e., interpolation of hydraulic parameters between measurement points); 2) variable flow densities; and 3) leakage into or out of the Culebra.

The transmissivity distributions calculated (Haug et al., 1987) are shown in Figure 4.17. The distribution was developed through the use of the SWIFT II code, test data from the H-3 multipad interference test, and adjustments for fluid density effects in the eastern half of the model.

Haug et al. (1987) also investigated whether or not a porous flow numerical approach could adequately model the Culebra Dolomite fractured system on a regional scale. Transient hydraulic responses to shaft sinking and sealing at hydropad H-3, and the H-3 multipad interference test, were modeled using both dual porosity and porous media methods.

TABLE 4.12 Summary of the analytical interpretation of results from the H-3 multipad interference test[a]

Well	Distance (m)[c]	Direction[c]	Time of first observation drawdown (hr)[d]	Delay in max drawdown (hrs)[d]	Unmodified interpretation[b]		Modified interpretation[b]		Water-level modification (m/day)
					Transmissivity[e]	Storativity	Transmissivity[e]	Storativity	
H-11b1	2423	S42E	79	51	1.4×10^{-5}	6.6×10^{-6}	7.3×10^{-6}	7.4×10^{-6}	8.6×10^{-3}
DOE-1	1606	S68E	57	48	9.9×10^{-6}	9.2×10^{-6}	5.9×10^{-6}	1.0×10^{-5}	5.5×10^{-3}
H-1	815	N19W	488	1423	8.9×10^{-7}	3.9×10^{-5}	4.9×10^{-7}	2.7×10^{-5}	2.64×10^{-2}
H-2b2	1270	N54W	433	1393	2.7×10^{-6}	4.5×10^{-5}	1.3×10^{-6}	3.0×10^{-5}	1.16×10^{-2}
WIPP-19	1875	N2E	1207	1855	3.1×10^{-6}	2.9×10^{-5}	--	--	--
WIPP-21	1437	N3E	437	678	1.2×10^{-6}	9.0×10^{-5}	--	--	--
WIPP-22	1739	N2E	990	727	1.7×10^{-6}	1.7×10^{-5}	--	--	--

[a] Slightly modified from data contained in Tables 3-1, 5-1, and 6-4 of Beauheim (1987a).

[b] Unmodified and modified transmissivities and storativities are apparent average values between H-3b2 and the indicated well, assuming radial flow to H-3b2.

[c] Distances and directions measured from H-3b2 to the indicated well.

[d] Times of the first drawdown and delay in the maximum drawdown are relative to time at which pump was turned on and off, respectively.

[e] Transmissivity in square meters per second.

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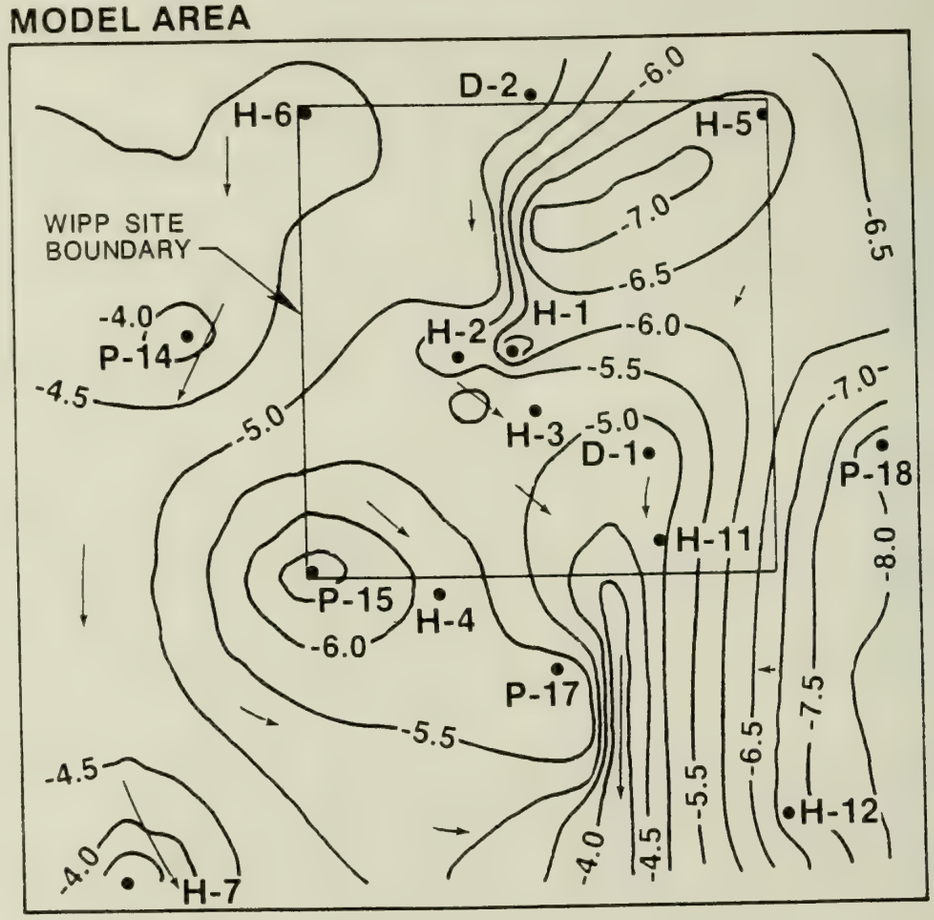


REF: LAPPIN, 1988.

NOTES: 1) UNITS: LOG m^2/s.

2) ● = DATA POINTS.

3) BASED ON DATA AVAILABLE AS OF APRIL 1986.

4) CONTOUR INTERVAL: 0.5 UNITS.

FIGURE 4.17
1987 CALCULATED TRANSMISSIVITIES AND FLOW DIRECTIONS FOR THE CULEBRA DOLOMITE MEMBER

The second multipad interference test was centered at hole WIPP-13 (Figure 4.12). The pumping phase at WIPP-13 took place between January 12, 1987 and February 17, 1987. Analytical estimation of hydraulic parameters resulting from the WIPP-13 test are discussed by Beauheim (1987c). These estimated hydraulic values for transmissivity and storativity are summarized in Table 4.13.

The numerical simulation of the Culebra hydrology, including the region stressed in the WIPP-13 tests, using the SWIFT II code is discussed in LaVenue et al. (1988). The emphasis of the numerical simulation study is on the Culebra hydrology prior to 1981 when construction of WIPP shafts imposed stress on the hydraulic system. Detailed interpretation of the WIPP-13 multipad interference test is still ongoing. However, transmissivities calculated for this modeling effort, using data collected through October 1987 based on kriging and steady-state calibration against estimated fresh-water levels, are shown in Figure 4.18. These transmissivity values are those used in the Case II release scenarios presented in Subsection 5.4.2.6 of the draft SEIS.

The third multipad interference test was centered at hydropad H-11 and was conducted during the summer of 1988. Evaluation of this interference test was underway at the time of the draft SEIS, but is now complete. As a result, the model was calibrated to data collected and analyzed through June, 1989. The transmissivity distribution resulting from this recent calibration is shown on Figure 4.18a. Comparison to the 1988 transmissivity distribution shown in Figure 4.18 indicates that no major changes have occurred in the distribution due to the recent calibration. The only noticeable change is a minor broadening of the 10^{-6} m^2/s contour. The implication of this is that the simulated flow rates are slightly increased. This revised transmissivity distribution was used for the calculation of Cases IIA (rev) and IIC (rev) in Subsection 5.4.2.6.

4.3.3.3 Basis for the Culebra Dolomite Flow and Transport Model. Modeling of the Culebra Dolomite hydrologic system has undergone dramatic changes since the FEIS. These changes reflect modifications to the conceptual model of the Culebra system. Current understanding shows that the Culebra Dolomite is a more complex flow system than originally conceptualized.

From 1983 through 1988, new hydrologic data for the Culebra Dolomite were collected and old data were reinterpreted, leading to a revised conceptual model of flow within the Culebra Dolomite. Although fracture characteristics of the Culebra Dolomite were recognized early in the hydrologic characterization of the WIPP site (Mercer and Orr, 1979), early models treated the Culebra as a simple porous media. Beauheim (1986) demonstrated the double-porosity hydraulic behavior of the Culebra during testing at well DOE-2. Subsequent analyses of pumping tests performed at H-3 (Beauheim, 1987a), WIPP-13 (Beauheim, 1987b), H-11 (Saulnier, 1987), and other wells (Beauheim, 1987c) showed that double-porosity behavior can be considered dominant wherever the Culebra has transmissivities greater than 10^{-6} m^2/s. In 1986, the DOE began a model-development process that will continue through at least 1989. The code used is SWIFT II (Reeves et al., 1986a, 1986b), an enhanced version of SWIFT that can simulate double-porosity flow and transport.

TABLE 4.13 Summary of the analytical interpretation of results from the WIPP-13 multipad interference test[a]

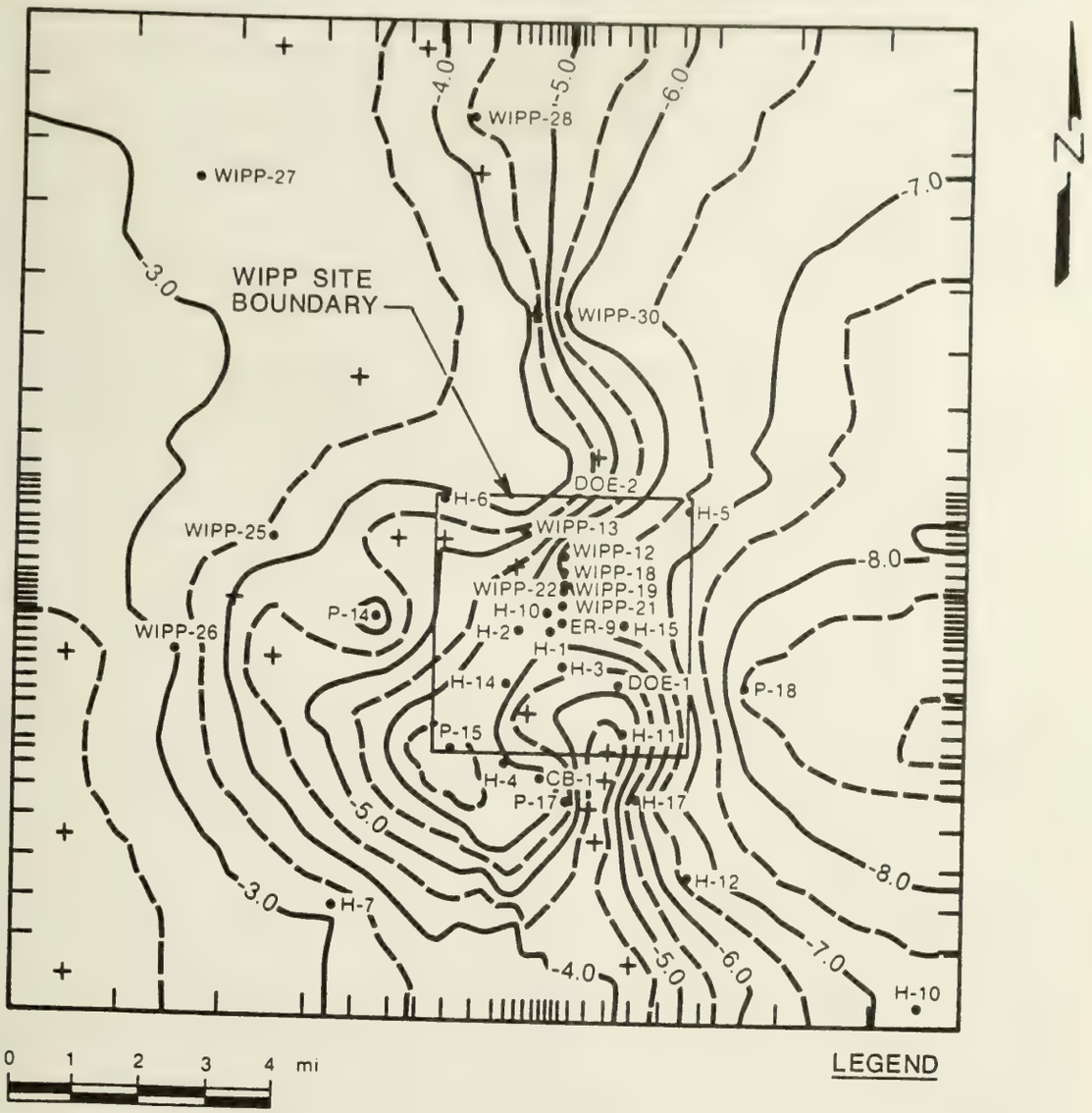
Well	Distance (m)[b]	Direction[b]	Time of first drawdown (hrs)[c]	Delay in maximum drawdown (hrs)[c]	Maximum drawdown (psi)	Transmissivity (m^2/s)[d]	Storativity	Water level modification (m/day)
WIPP-13	0	--	0	0	23.5	7.4×10^{-5}	--	--
DOE-2	1475	N45E	1	1	17.3	7.1×10^{-5}	5.1×10^{-6}	--
H-6a	2192	N20W	8	5	7.7	7.6×10^{-5}	8.2×10^{-6}	--
H-6b	2189	N20W	8	5	7.9	7.4×10^{-5}	7.9×10^{-6}	--
WIPP-30	5587	N12E	61	136	4.9	3.0×10^{-5}	5.6×10^{-6}	5.3×10^{-3}
WIPP-12	1283	S55E	74	186	11.9	8.5×10^{-6}	3.6×10^{-5}	4.5×10^{-3}
WIPP-18	1521	S45E	74	86	9.3	2.5×10^{-5}	4.0×10^{-5}	3.6×10^{-3}
WIPP-19	1823	S37E	102	186	7.2	2.6×10^{-5}	4.0×10^{-5}	7.6×10^{-3}
WIPP-21	2216	S29E	133	396	3.6	2.4×10^{-5}	4.3×10^{-5}	1.7×10^{-2}
WIPP-22	1933	S34E	102	286	5.7	2.0×10^{-5}	4.7×10^{-5}	8.2×10^{-3}
H-1	2676	S16E	600	2086	1.1	2.2×10^{-5}	1.3×10^{-4}	1.4×10^{-2}
H-2b2	2597	S20E	445	986	1.4	1.7×10^{-5}	7.3×10^{-5}	6.0×10^{-3}
ERDA-9	2518	S24E	550	396	2.0	2.4×10^{-5}	5.4×10^{-5}	1.6×10^{-2}
Exhaust shaft	2414	S26E	400	336	3	3.0×10^{-5}	5.5×10^{-5}	2.9×10^{-2}
P-14	4228	S58W	71	56	0.8	2.8×10^{-4}	5.2×10^{-5}	--
WIPP-25	6264	S88W	76	26	0.3	7.0×10^{-4}	6.4×10^{-5}	--

a Slightly modified from data contained in Tables 3-1, 5-1, and 6-1 of Beauheim (1987c).

b Distance and direction measured from WIPP-13.

c The time of the first drawdown and the delay in the maximum drawdown are relative to the time at which the pump was turned on and off, respectively.

d Apparent and effective transmissivity (T) and storativity (S) assume homogenous properties between WIPP-13 and given well, as well as radial flow into WIPP-13.

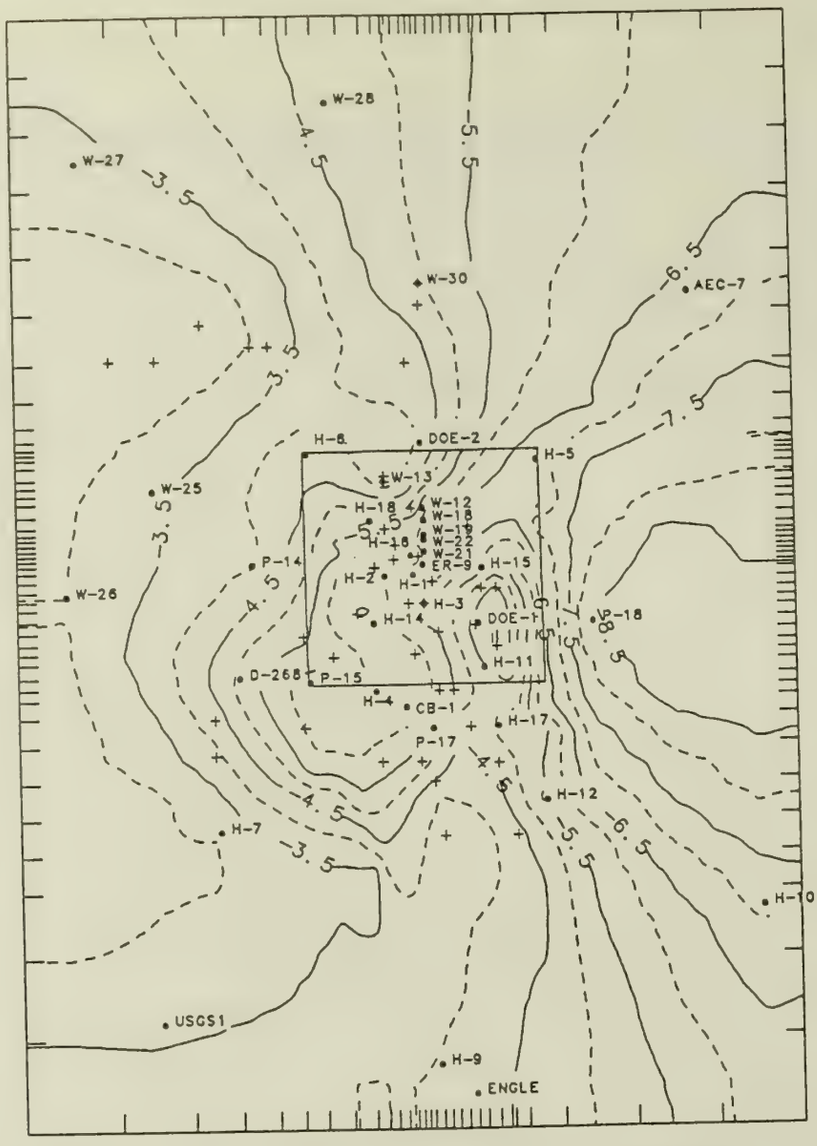


NOTES: 1) TRANSMISSIVITIES IN LOG m^2/sec

2) CONTOUR INTERVAL: 0.5 UNITS

REF: LAVENUE et al., 1988.

FIGURE 4.18
1988 CALCULATED TRANSMISSIVITIES FOR THE CULEBRA DOLOMITE MEMBER AT AND NEAR THE WIPP SITE



NOTES: 1) Transmissivities in m^2/s
2) Contour Scale: Logarithmic
3) Contour Interval: 0.5 log m^2/s

REF: LAVENUE et al., 1989.

FIGURE 4.18a
1989 TRANSIENT CALIBRATED TRANSMISSIVITY FIELD OF THE CULEBRA DOLOMITE

Model development by LaVenue et al. (1988) incorporated new data on transmissivities and hydraulic heads, the results of the multipad interference tests. Calibration of the model of LaVenue et al. (1988) indicated a high-transmissivity feature south of H-11 and DOE-1. The feature was somewhat wider in the east-west direction, and the transmissivities calculated for this zone (Figure 4.18) are approximately four times higher than those reported in Haug et al. (1987) (Figure 4.17). Although particle travel time from the center of the WIPP emplacement panels to the southern WIPP site boundary (approximately 3 km), along the present hydraulic gradient, was computed to be approximately 13,000 years (LaVenue et al., 1988), this computation is only an indicator of transport since it does not take into account dispersion and retardation. Subsection 5.4 describes transport conditions for various simulation cases. The model of LaVenue et al. (1988) has been expanded to accommodate the calibration to both steady-state and all major transient flow stresses within the Culebra.

Transient hydraulic stresses that are included in this most recent model-calibration procedure consist of the WIPP shaft construction; the H-3, WIPP-13, and H-11 multipad pumping tests; and the H-4 tracer test. This model is termed the "adjoint-sensitivity approach" and allows for minor modification of transmissivity or storativity distributions to improve the model fit to the observed hydraulic heads. The adjoint-sensitivity approach also permits modeling of different conceptualizations of the flow system that fit the observed head distribution equally well, but may result in different flow paths or travel times from the waste-disposal panels to the site boundary.

The data collection phase of the Culebra hydrologic characterization program is complete, and no new wells are currently planned. Thus, modeling is subject to the limitations of the current data base. These limitations do not appear to be major. The expanded version of the model of LaVenue et al. (1988), which has been calibrated to all major transient stresses (i.e., shafts and multipad tests), has been used to simulate the modified Cases IIA(rev) and IIC(rev) presented in Subsection 5.4.

Within the context of the current hydrologic code used to simulate the Culebra flow and transport characteristics, various assumptions have been made. First, the Culebra has been assumed to be vertically homogeneous, with hydraulic conductivity, and hence, flow, distributed equally throughout the thickness of the unit. In limited testing performed at five locations, Mercer and Orr (1979) and Beauheim (1987c) have shown hydraulic-conductivity variations ranging from a factor of 2 to a factor of 5 between different intervals within the Culebra (i.e., sections on the order of 1 or more meters thick). However, the area flow modeling of the Culebra relies on transmissivity data, not hydraulic-conductivity data, and flow and transport modeling should be reliable.

A second assumption used in the Culebra flow and transport modeling in this report (as opposed to Haug et al., 1987) is that the Culebra is locally completely confined, with no vertical flow either in or out, and that both brine-density distribution and head potential are at steady state. Although the impact should be minimal, to date the uncertainty of the modeling related to the transient setting has not been fully evaluated.

A third assumption of the current generation of Culebra hydrologic models is that the Culebra is locally a hydraulically isotropic medium (having uniform properties in all directions). Gonzalez (1983) and Saulnier (1987) reported evidence that the ratios of horizontal anisotropy (exhibition of properties that are different in one or more directions) ratios range from 1.6/1 to 2.7/1 within the Culebra. Implementing an

anisotropy ratio of 2.7/1 within the model would only require changing the current effective transmissivities by a factor of 1.6, which is well within the existing calibration uncertainty.

4.3.3.4 Geochemical Environment Within the Rustler Formation. As detailed in the preceding subsections, the Rustler Formation is composed of three beds of anhydrite, rock salt, and clays separated by two beds of finely crystalline gypsiferous dolomite (Lappin, 1988).

Because of the potential importance of the Culebra Dolomite as a migration pathway, numerous wells have been emplaced within the unit. Chemical analyses of samples from these wells indicate that there are four hydrochemical facies (distinguishable water quality types) within this unit (Lappin, 1988). The distribution of these facies is shown in Figure 4.19. The hydrochemical facies are distinguished in terms of their major constituents.

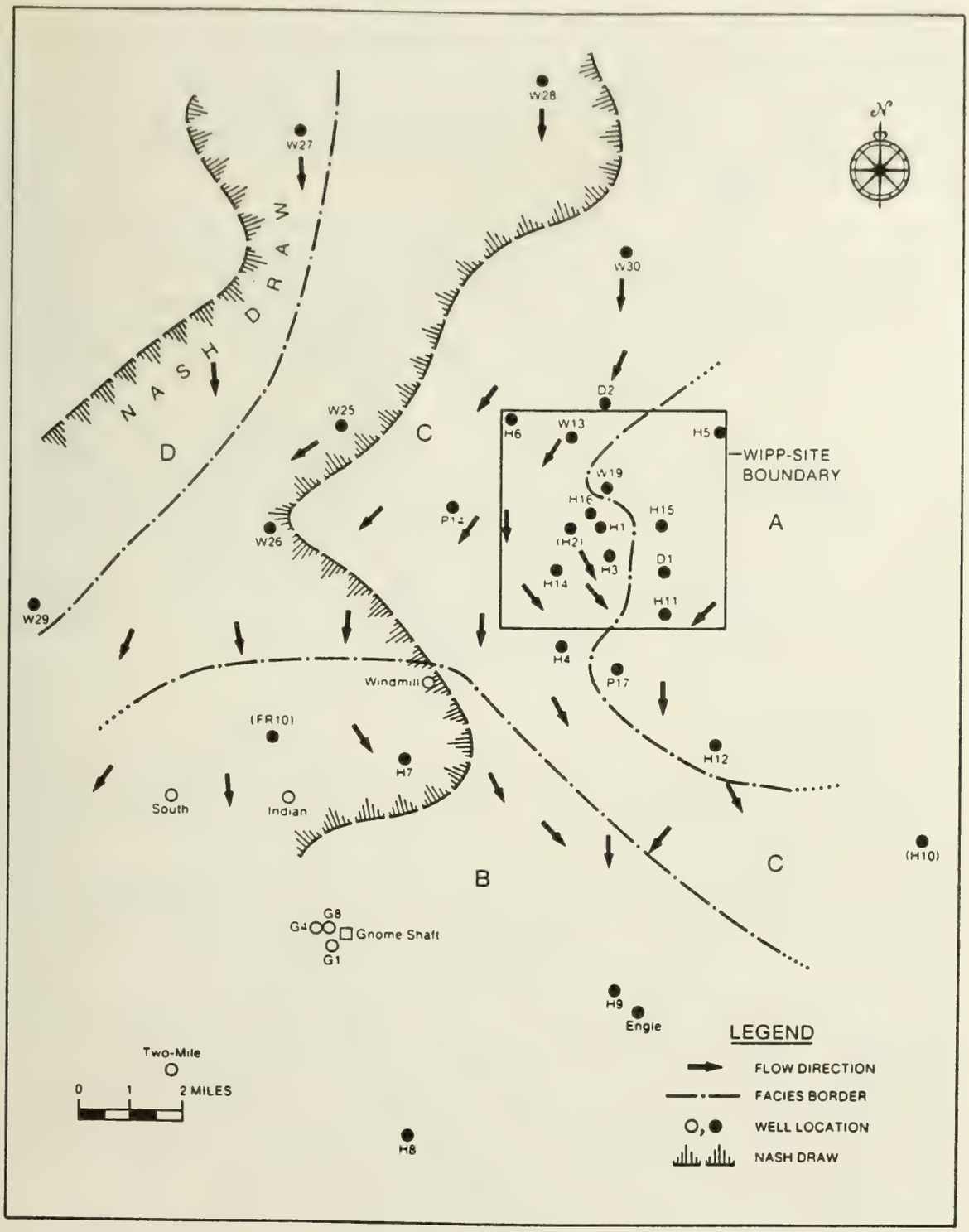
- Zone A brines are saline (2 to 3 molal), contain high concentrations of sodium and chloride (Na and Cl), and have magnesium calcium (Mg/Ca) molar ratios greater than 1.2. The Zone A brines are limited to the eastern portion of the WIPP site.

- Zone B groundwaters are relatively fresh (<0.1 molal). Dominant solutes are calcium (Ca^{2+}) and sulfate (SO_4^{-2}). The Zone B fluids are restricted to the southern portion of the region.

- Zone C groundwaters are of intermediate ionic strength, 0.3 to 1.6 molal, and are distinguished by Mg/Ca molar ratios less than 1.2. These fluids are found within a central zone that divides into two branches as one progresses to the southwest and southeast (Figure 4.19).

- Zone D fluids have anomalously high concentrations of dissolved solids, 3 to 7 molal, and potassium/sodium (K/Na) weight ratios that are at least twice that of the other brines (0.2 vs. 0.01 to 0.09). Zone D is limited to the western portions of Nash Draw where the Culebra waters have been contaminated by potash-mining activities (near wells WIPP-27 and WIPP-29).

Chapman (1988) observed that salinities in the Culebra Dolomite generally increase from west to east, where increases in potassium (K) and magnesium (Mg) concentrations correspond to an increase in chlorine (Cl). In addition, Total Dissolved Solids (TDS) decrease by an order of magnitude, and hydrochemical facies change from sodium chloride (NaCl) to calcium sulfate ($CaSO_{4)}$ along the groundwater flow path to the south. The distribution of salinities and hydrochemical facies in the Culebra Dolomite corresponds to the amount of evaporite dissolution in the Rustler Formation (Chapman, 1988).



REF: LAVENUE et al., 1988.

FIGURE 4.19
SUMMARY OF HYDROCHEMICAL FACIES AND LOCAL FLOW DIRECTIONS IN THE CULEBRA DOLOMITE MEMBER

Siegel et al. (in Lappin, 1988) calculated mineral saturation indices and examined interelement correlations to identify chemical reactions that control the chemistry of Culebra waters. These results suggest that the Culebra fluids are variously buffered by the dissolution of rock salt, gypsum/anhydrite, and carbonates, and in some cases the magnesium ion (Mg^{2+}) and silica (SiO_2) are added to the groundwater in response to clay diagenesis. Studies looking for a correlation between Culebra mineralogy and hydrochemical facies have yet to be completed.

Ramey (1985) reviewed water quality analyses performed by the U.S. Geological Survey collected from the Rustler Formation. Ramey (1985) determined that three fluid-bearing zones are chemically separate from one another at the WIPP site; however, these zones progressively merge towards the west into Nash Draw. The fluids present at the Rustler-Salado contact approach saturation with respect to sodium chloride (NaCl) (Ramey, 1985). The Culebra groundwater is undersaturated with respect to sodium chloride (NaCl) (Lappin, 1988; Ramey, 1985).

Approximately 85 percent of the bulk rock matrix of the Culebra Dolomite is composed of relatively pure dolomite ($CaMg(CO_3)_2$). Accessory minerals include gypsum ($CaSO_4 \cdot 2H_2O$), calcite ($CaCO_3$), and clays, which are distributed heterogeneously both horizontally and vertically. Fracture fillings include both clays and gypsum. Gypsum is also found as a filling in solution cavities and holes within the Culebra Formation. Detailed investigations of the clays by Sewards et al. (1989) indicate that an ordered, mixed-layer illite-smectite is the most abundant clay mineral and, indeed, the most abundant mineral after dolomite. Additional sheet silicate minerals include illite, chlorite, and amesite, a serpentine-like mineral.

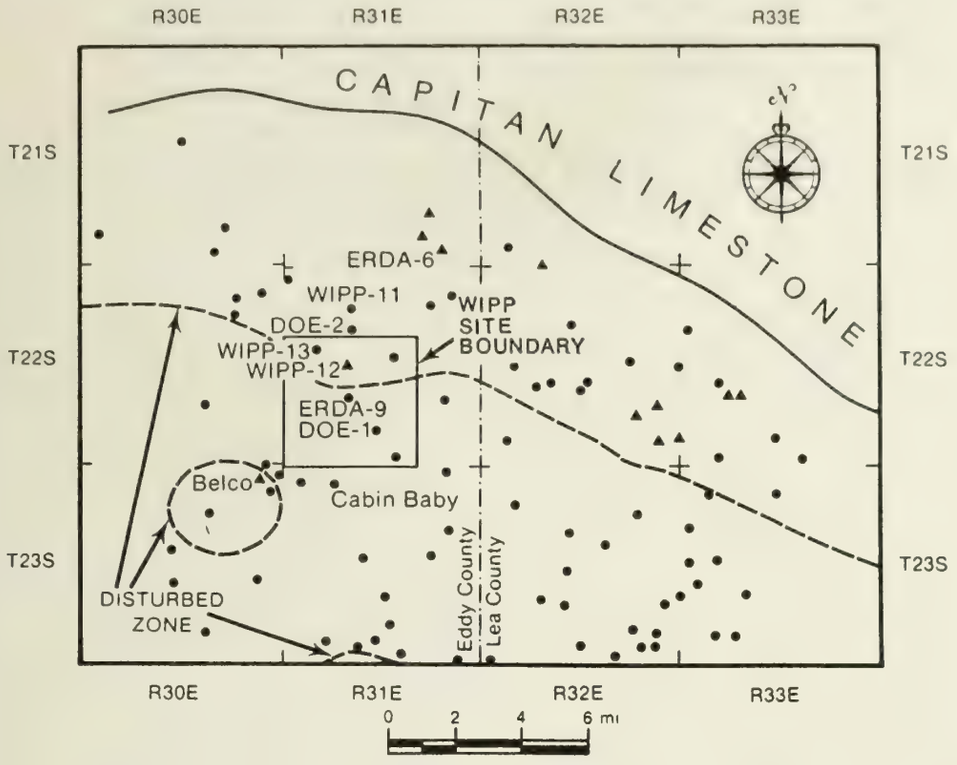
4.3.4 Castile Formation

The Castile Formation lies below the Salado Formation and over the Bell Canyon Formation of the Delaware Mountain Group. At and near the WIPP, the Castile Formation consists lithologically of three anhydrite units separated by two halite units. Total thickness of the Castile is approximately 1,312 ft.

Figure 4.5 shows the distribution of the anhydrites (Anhydrite I at the bottom and Anhydrite III at the top) and the intervening halite units (Lappin, 1988). This figure represents the current understanding of the Castile Formation at and near the WIPP.

4.3.4.1 Regional and Local Variability, Deformation, and Dissolution of the Castile Formation. Concern regarding the variability of the stratigraphic thickness of the Castile and its potential cause by regional or localized dissolution was expressed prior to the FEIS (Anderson, 1978) and more recently by Davies (1983). The thickness of the Castile varies regionally and locally within the WIPP site. The northern portion of the WIPP (holes WIPP-12, DOE-2 and WIPP-11) lies within the disturbed zone described by Borns et al. (1983) (Figure 4.20), which is characterized by deformation and variability in the thickness of the Castile and Salado Formations.

Much of the thickness variability shown in Figure 4.5 is within the halite units. However, Anhydrites II and III also vary in thickness. The relationship between the



LEGEND

REF: LAPPIN, 1988.

▲ BOREHOLE IN WHICH CASTILE FORMATION BRINE WAS ENCOUNTERED

● BOREHOLE THAT PENETRATED THE CASTILE FORMATION BUT DID NOT ENCOUNTER BRINE (ERDA-9 IS INCLUDED FOR REFERENCE ONLY)

FIGURE 4.20
GENERALIZED DISTRIBUTION OF CASTILE FORMATION BRINE OCCURRENCES AND APPROXIMATE EXTENT OF THE CASTILE "DISTURBED ZONE" IN THE NORTHERN DELAWARE BASIN

thickness of the halites and the anhydrites indicates unusually thick halites coupled with unusually thin anhydrites and vice versa. This thickness relationship is inconsistent with the concept of dissolution being the prime cause of the variation in the Castile Formation thickness.

A similar relationship is seen between the halites of the Salado and the predominant anhydrites of the Castile. This would indicate that the variable thicknesses of the halite and the anhydrite are due to internally compensating variations in the thickness of these materials. The origin of this compensating relationship may be depositional (Lambert, 1983; Borns and Shaffer, 1985) or a postdeposition gravity deformation (Borns et al., 1983).

Borns et al. (1983) and Borns (1983) cite considerable evidence for both syndepositional (concurrent with deposition) and postdepositional deformation of the Castile Formation. Concurrent depositional deformation is probably the result of gravity acting as the driving force along depositional slopes or in response to density contrasts. Postdepositional deformation results from high-stress-level anhydrous deformation (Munson, 1979) or pressure-solution deformation (Borns et al., 1983).

Recent studies indicate that the fluid content within the Salado Formation is as high as 2 percent, more than adequate for pressure-solution deformation (Borns, 1987). These studies indicate that much of the deformation of the Castile Formation may have been concurrent with deposition (i.e., Permian).

4.3.4.2 Occurrence and Characteristics of Pressurized Brines. The potential for the presence of pressurized brines within the Castile was recognized at the time of the FEIS. Seismic reflection data available at the time of the FEIS confirmed the presence of an area north of the site that exhibits nonuniform response to seismic waves. This zone (Figure 4.20) is the disturbed zone of Borns et al. (1983). Pressurized brines were encountered in hydrocarbon exploration drillholes and in ERDA-6 within the disturbed zone prior to the FEIS. In addition, brines were encountered to the southwest of the WIPP at the Belco well.

Investigation of pressurized brine in the Castile Formation has continued since the FEIS. These studies have included reopening and testing hole ERDA-6, deepening hole WIPP-12, investigating the geophysical potential for the presence of Castile brines underlying the WIPP, and conducting geochemical evaluations to determine the origin of the Castile brines. In these investigations, pressurized brines were encountered at a depth of about 3,000 ft in hole WIPP-12, and the disturbed zone and potential brine locations were delineated. A relatively recent origin was postulated for the brine.

Popielak et al. (1983) reported the results of the testing and sampling investigation in drillholes ERDA-6 and WIPP-12. The conclusions made from the ERDA-6 and WIPP-12 studies can be summarized as follows:

- The brines originated from ancient seawater, and there is no evidence of contribution from contemporary rain water.

- The gas and brine characteristics at ERDA-6 and WIPP-12 are distinctly different from each other and from local groundwaters.

- These brines are at or near salt saturation and have little potential to dissolve evaporite deposits.

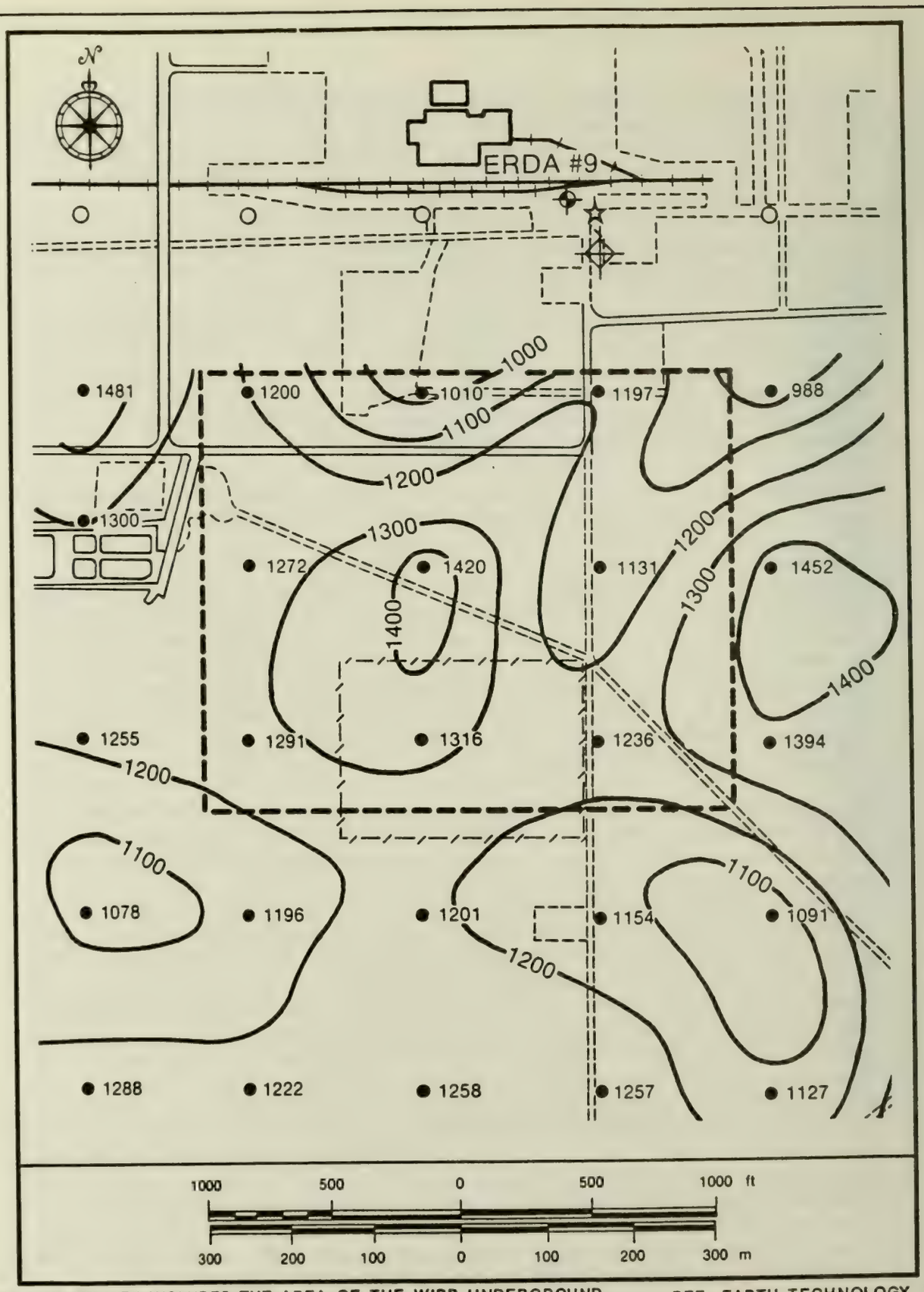
- The brine reservoirs at ERDA-6 and WIPP-12 were estimated to hold 630,000 and 17,000,000 barrels, respectively.

- The hydraulic heads measured in the brine reservoirs are great enough to reach the ground surface in an open borehole.

In a later study of brine geochemistry, Lambert and Carter (1984) indicate, on the basis of uranium disequilibrium, that the brines at ERDA-6 and WIPP-12 are between 360,000 and 800,000 years old and thus not ancient (Permian) sea water. Because of these ages, Lambert and Carter conclude that the production of the brines must be episodic. This episodic process could have resulted from an intermittent hydraulic connection between the Capitan limestone and Castile anhydrites.

Geophysical studies reported by Borns et al. (1983) provided a delineation of the extent of the disturbed zone in the vicinity of the WIPP (Figure 4.20). These studies were, however, unsuccessful in assessing the presence of Castile brines beneath the WIPP. A subsequent geophysical survey was conducted by Earth Technology (1987), using time-domain electromagnetic (TDEM) methods. This survey was conducted over WIPP-12, ERDA-6, DOE-1, and the waste disposal area. The results of this survey are presented in Figure 4.21. A continuous deep conducting zone underlies the region of the WIPP waste-emplacement panels (Figure 4.21). Conducting zones indicated at a depth of 3,935 ft or less may be due to the presence of Castile brine, given the estimated +/-246 ft in depth resolution and possible stratigraphic variability. Conductors indicated at greater depth are probably due to sandstone or shale in the underlying Bell Canyon Formation.

An earlier site proposed for the WIPP, approximately 6 miles north of the present site, was rejected partly on the basis of results obtained in hole ERDA-6 (Figure 4.20), which indicates both the presence of pressurized brine in Castile anhydrites and, more importantly, strong deformation of the overlying Salado Formation (FEIS, Subsection 2.2.3). The deformation of the Salado would have required that a horizontal repository cross several stratigraphic contacts, including one or more anhydrite marker beds, and would have been in an area with increased potential for future deformation. The stratigraphic complexity in the Salado was especially important, because the proposed repository had two separate levels, one near the present repository horizon for RH TRU and CH TRU waste, and a deeper level near the Salado/Castile contact zone for defense high-level waste (DHLW). Hole WIPP-12 (Figure 4.20) also encountered pressurized brine in the Castile, but the overlying Salado at this location is not significantly deformed (Figure 4.5). After brine was encountered in WIPP-12, the WIPP underground workings were reoriented to their present position. The major reason for this reorientation was to accommodate a request from the Environmental Evaluation Group (EEG). Calculations performed by both the WIPP project and the EEG (Channell, 1982) indicated that the presence of pressurized Castile brine beneath the repository would not have unacceptable impact. The present orientation of the WIPP underground workings, with waste emplacement panels south of hole ERDA-9, has allowed construction within a nearly flat-lying portion of the Salado.



NOTE: THE SURVEY INCLUDES THE AREA OF THE WIPP UNDERGROUND REPOSITORY, AND THE HEAVILY DASHED RECTANGLE OUTLINES THE SURFACE PROJECTION OF THE WIPP UNDERGROUND REPOSITORY. CONTOURS ARE IN METERS.

REF: EARTH TECHNOLOGY, 1987.

FIGURE 4.21

CONTOUR MAP OF APPARENT DEPTH TO FIRST MAJOR DEEP CONDUCTOR

The presence of Castile brine beneath the repository is of concern only in the event of human intrusion (Cases II A, B, C, D in Subsection 5.4). In this report, the brines underlying the repository are assumed to be present, as they are at WIPP-12. However, there is no direct pathway from the assumed brine reservoir to the repository at present since, by design, no drillholes through the area enclosed by the WIPP workings have been allowed to penetrate down to the stratigraphic interval potentially containing Castile brines.

4.3.5 Bell Canyon Formation

The Bell Canyon Formation, which underlies the Castile Formation and is the uppermost formation in the Delaware Mountain Group, is of interest to WIPP-site characterization because it is the first laterally continuous, water-bearing zone below the underground WIPP facilities. It has been considered as providing a potential local mechanism for the dissolution of the overlying evaporite sequences.

4.3.5.1 Dissolution Potential of the Bell Canyon Formation. The Bell Canyon Formation has been proposed as a point-source for the dissolution of the overlying evaporite sequences by Anderson (1978, 1981) and Davies (1983). Wood et al. (1982) concluded that, even considering maximum potential dissolution rates at the top of the Bell Canyon Formation, no significant evaporite dissolution would occur at the WIPP facility for at least 10,000 years. Additionally, Lambert (1983) concluded that the isotopic compositions of water in the Bell Canyon Formation show no evidence of a modern hydraulic connection with a salt unsaturated source of fluids like the Capitan Limestone. Therefore, the Bell Canyon Formation is not recharged with groundwater capable of dissolving overlying units over a long period of time.

4.3.5.2 Potential for Fluid Flow Between the Bell Canyon and the Rustler Formations. In the event of a drillhole interconnecting the Bell Canyon Formation and the Rustler Formation, the hydraulic pressure within the Bell Canyon could drive groundwater above the base of the Culebra Dolomite Member (Saulnier, 1987; Mercer et al., 1987; LaVenue et al., 1988; Uhland et al., 1987).

The freshwater head for the Bell Canyon at the center of the WIPP was calculated by Mercer et al. (1987) to be approximately 3,412 ft. This would be 394 ft greater than the expected density-corrected pressure for the Culebra at the same location and indicates that, under these conditions, upward vertical flow could occur. However, Lappin (1988) argues that in the event of a breach interconnecting the Bell Canyon to the overlying units, local dissolution of the Salado would occur, so that the intruding fluids would become a saturated brine solution. Given this assumption, the hydraulic head of the Bell Canyon fluids would rise to an elevation of approximately 2,739 ft in an open hole below the base of the Culebra Dolomite. This would result in an effective downward flow from the Culebra to the lower units.

Lappin (1988) agrees that the calculated direction of fluid flow depends on fluid densities and that fluid flow might move upward until the Bell Canyon and Culebra fluids were saturated with salt. This scenario does not take into account the potential for gas pressure generation in the WIPP facility, which could provide driving pressure levels in both an upward and a downward direction.

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5.0 ENVIRONMENTAL CONSEQUENCES

This section discusses the potential environmental consequences of the Proposed Action, No Action, and the Alternative Action.

Subsection 5.1 provides an update of information discussed in the FEIS based on new information obtained since 1980 and discusses impacts that have occurred since 1982 as a result of WIPP construction activities. The information presented in Subsection 5.1 is not considered to be a substantial change from impacts foreseen in the FEIS.

Subsection 5.2 discusses impacts of the SEIS Proposed Action. Impacts at the WIPP during the Test and Disposal Phases remain the same as impacts described in the FEIS except as modified in Subsection 5.2. That subsection begins with an update of FEIS Section 9.8 which dealt with impacts of retrieval and processing of waste at the Idaho National Engineering Laboratory for shipment to the WIPP. Subsections 5.2.2, 5.2.3, and 5.2.4 evaluate the transportation, radiological, and hazardous chemical impacts, respectively, of the Proposed Action.

Subsection 5.3 evaluates impacts associated with the alternative of conducting bin-scale tests at a location other than the WIPP underground (Alternative Action). Also provided are the impacts of the decommissioning and long-term performance of the WIPP as a permanent waste repository are found in Subsection 5.4. The impacts of the No Action Alternative are found in Subsection 5.5.

5.1 ENVIRONMENTAL IMPACTS OF IMPLEMENTATION OF FEIS SELECTED ALTERNATIVE

This subsection updates the FEIS by describing impacts of construction as they have occurred and also discusses the findings of research since 1980.

5.1.1 Biology

Sections 9.2.1 and 9.3.1 of the FEIS describe the expected impacts on the biota from the construction and operation of the WIPP, respectively. The following discussion summarizes and updates the findings contained in the FEIS and the annual reports of the Ecological Monitoring Program (EMP) (Reith and Louderbough, 1986; Fischer et al., 1985; Fischer, 1987, 1988).

- Vegetation. Impacts on vegetation currently consist of the continued use of cleared areas and the dispersion of salt and other mined-rock particles at the surface. Since the berms of the salt pile channel runoff from the salt pile to an evaporation pond, nearly all dispersion occurs through the resuspension, transport, and deposition of salt particles by wind. Observations at the Gnome-site salt pile indicate that these impacts are not

considered to be major (i.e., the vegetation in the area shows no identifiable salt-related stress except for a single mesquite tree growing on one of the salt piles).

Vegetation and soil chemistry at the WIPP site and adjacent areas have been monitored since 1984 in permanent ecological monitoring plots to assess the impacts of the salt. Parameters that are monitored include foliar cover for all species, density of annual species, species richness, vegetative community structure, and soil properties (SEIS Subsection 2.9.2). The ecological impacts of excavated salt stored on the surface have been shown by the results of the monitoring programs to be considerably less than expected in the FEIS, as discussed below.

Ecological monitoring results showed a decrease in foliar cover for shrubs from spring to fall in the 1985 to 1987 study period. Both perennial and annual forbs and perennial grasses increased in foliar cover between 1985 and 1986 but decreased in 1987. These changes are believed to be the result of natural processes (e.g., available moisture, forage utilization) rather than the effects of the salt pile.

Annual species density showed a large fluctuation between 1985 and 1987, when high spring precipitation produced a high emergence of annual plants, and in 1986, when low spring rainfall may have delayed or hindered germination. In 1985 and 1987, the total densities of these plants decreased from spring to fall except in 1986 when there was a slight seasonal gain. This parameter is influenced by a number of factors, including soil types, seed viability, temperatures, size of seed crop from the previous year, and amount of grazing by cattle and herbivorous wildlife.

The concentrations of soluble ions in surficial soil samples have been most affected by salt dispersion. These concentrations, particularly of sodium and chloride, have been substantially higher at monitoring plots adjacent to salt piles than at control plots, with the highest concentrations occurring in the spring. This pattern suggests that salt is picked up and deposited downwind by the strong spring winds; the salts are then leached downward through the sandy soil during summer rainstorms. The most recent information indicates that no salt accumulations are occurring at the surface or in the top 75 centimeters of soil. Long-term buildup of salt concentrations are not expected to occur. The salt levels in the soil do not appear to inhibit plant species diversity or abundance. These studies will continue as part of the Ecological Monitoring Program.

- Wildlife. Data concerning the populations of breeding birds and small nocturnal mammals are being collected in two transects at the WIPP site and two transects at control locations. These data will be used to assess the impacts of habitat modifications associated with both construction and operational activities. Eleven species of dominant breeding birds were recorded in both the WIPP site and control transects throughout the years between 1984 and 1987; the most abundant of these species were the black-

throated sparrow and pyrrhuloxia. Ten less abundant species were recorded along control transects, but only six of these species were found in the WIPP site transects. Eleven additional species were found only in WIPP site transects; the northern oriole (*Icterus galbula*) and the greater roadrunner (*Geococcyx californianus*) were the most numerous of these. A total of 28 species was recorded in the WIPP site transects, while 21 species were recorded in control transects.

A total of 21 species of raptors has been recorded to date by surveys for the WIPP Biology Program (initiated in 1975) and its successor, the EMP. Two species, the Harris hawk and Swainson's hawk (*Buteo swainsoni*), were found to breed near the WIPP site in unusually large numbers. This was an important finding because both species are uncommon in the United States and are of uncertain status throughout most of their natural range. Since human influence adversely affects the nesting success of these birds, field work schedules were modified to avoid disturbance of active nests.

Mammal population densities were estimated by trap, mark, and recapture techniques performed over the 1985-1987 period. The species considered were Ord's kangaroo rat (*Dipodomys ordii*), plains pocket mouse (*Perognathus flavescans*), northern grasshopper mouse (*Onychomys leucogaster*), southern plains woodrat (*Neotoma micropus*), white-footed and deer mice (*Peromyscus leucopus* and *maniculatus*), and hispid cotton rat (*Sigmodon hispidus*). Of these, the Ord's kangaroo rat and the plains pocket mouse were the most common, while the hispid cotton rat and the white-footed and deer mice were the least abundant. The kangaroo rat was present in all transects during all years. The pocket mouse, though present in all years and in all transects, was characterized by an extremely low population in 1986.

Ongoing studies seem to indicate that human activity has a disturbing influence on some bird species and displaces some individuals or species. Mammal populations show large natural fluctuations, but do not appear to have been influenced by WIPP construction activities.

5.1.2 Socioeconomics

Socioeconomic evaluations for the WIPP were presented in the 1980 FEIS in Subsections 6.6, 6.12, and 9.4.

Socioeconomic impacts on southeastern New Mexico were studied for FY 1982 (Adcock et al., 1983), FY 1987 (Lansford et al., 1988a), and FY 1988 (Adcock et al., 1989). A comparison of current economic conditions and impacts with those projected in the FEIS shows some dramatic differences. The differences are mainly a result of WIPP design changes, increased construction efficiency, and cyclic economic conditions (reductions in potash, oil, and gas production). The WIPP-related changes had a stabilizing effect on the local economy, particularly in Eddy County.

The primary area of socioeconomic impact defined in the 1980 FEIS was, and continues to be, Eddy and Lea Counties, or southeastern New Mexico. The local WIPP funding, or direct impact on this area, was $72.5 and $95.3 million in Federal FY 1987 and FY 1988, respectively. This includes monies for local DOE offices, Sandia National Laboratory, Westinghouse Electric Corp., and various on-site support contractors. Also included are grants, community assistance, and out-of-region expenditures made through or by the local WIPP project office. Local spending was mainly for wages and salaries, materials and services, capital equipment, and construction. Subsequent spending of these salaries and wages and other indirect effects pushed the total impact of the WIPP project to an estimated $159.4 million in FY 1987 and $208.9 million in FY 1988 (Lansford et al., 1988b; Adcock et al., 1989). The data for FY 1988 are given in Table 5.1.

WIPP's direct activity created an average of 530 and 661 jobs in FY 1987 and FY 1988, respectively. Total employment impacts were 1,434 and 1,814 new jobs in FY 1987 and FY 1988, respectively.

The WIPP project injected more than $18 million in personal income directly into the local economy in FY 1987 and more than $24 million in FY 1988. The WIPP-related purchases and respending generated additional personal income through wages and salaries of individuals not directly connected to the WIPP. The estimated total personal income additions from the WIPP activity in southeastern New Mexico were $38 million in FY 1987 and over $50 million in FY 1988.

During 1987, the DOE Albuquerque Operations Office (DOE/AL) announced a commitment to assemble the TRUPACT-II containers in southeastern New Mexico. The contract for this assembly facility was awarded to a Carlsbad firm. Construction of the facility was completed in 1987 with a total cost of about $800,000. The assembly of the TRUPACT-II containers created 17 new jobs in Carlsbad during 1987, and about 40 additional jobs in 1988.

In November 1988, DOE/AL signed a contract with a Farmington, New Mexico, firm to transport waste in TRUPACT-II containers to the WIPP from the generator sites. The contract is estimated to be worth up to $5.8 million over a period of up to five years.

With the proposed initiation of the Test Phase in 1990 and continuing for approximately five years, the annual total economic impact would range from about $150 million to $185 million (constant 1990 dollars). The direct employment for the regional WIPP activity would range between 650 and 660 jobs during this time period. The annual total employment range would be 1,650 to 1,800 jobs, depending on the regional expenditure patterns during this period.

By 1995 the WIPP would have reached steady operation with a funding (in 1990 constant dollars) of $67 million annually. At this level of funding, the annual total economic impact on southeastern New Mexico is projected to be $160.5 million. The steady-state period would continue through FY 2013. Direct annual employment would average 680 jobs. Projected indirect (including induced effects) employment effects would be about 930 jobs. Thus, the total employment effect of the WIPP during this period would be about 1,610 jobs, either created or indirectly supported. During this

TABLE 5.1 The WIPP's influence on the regional economies of Eddy and Lea Counties, FY 1988

	WIPP activities	Regional economies	WIPP % of regional economies
	(Dollars in Millions)		
Economic Activity			
Direct expenditures	$ 95.3		
Indirect and induced[a]	113.6		
Total	$208.9	$4,000.0	5.2
Income			
Salaries and wages[b]	$ 24.3		
Indirect and induced[a]	26.2		
Total	$50.5	$1,400.0[c]	3.6
	(Number of Employees)		
Employment			
Direct	661		
Indirect and induced[a]	1,153		
Total	1,814	39,500[d]	4.6

[a] Based on an econometric model maintained at DOE/AL, Los Alamos National Laboratory, and the Agricultural Economics Department of New Mexico State University.

[b] Less the fringe benefits that are not counted as personal income.

[c] Extrapolated 1984-1986 personal income data from Bureau of Economic Analysis, U.S. Department of Commerce.

[d] Table A, New Mexico Department of Labor, 1989.

period, annual total personal income would be increased by $43 million from all impacted sources. Over the 20-year Disposal Phase, the WIPP would add over $1 billion (in 1990 constant dollars) to regional total personal income.

During the same period, local and state tax and fee revenues from all sources related to the WIPP would be increased by $5.4 million annually or over $100 million for the operating period.

After FY 2013, decommissioning activities are planned to begin and would continue for up to five years. During this period the WIPP funding and employment would decrease.

Considering the total period from FY 1990 through FY 2018, funding for the WIPP, in terms of constant 1990 dollars, would be over $2.1 billion. The economic activity multipliers used in the FY 1987 and FY 1988 studies by Lansford and Adcock (Lansford et al., 1988b; Adcock et al., 1989) were 2.20 and 2.19, respectively. The steady-state multiplier determined for the report was 2.36--slightly higher due to a higher proportion of labor costs and increased proportional spending in the local area. The combination of these multipliers on the WIPP funding levels shows a total impact on regional economic activity of over $4.3 billion from FY 1990 through decommissioning.

5.1.3 Land Use

The detailed evaluations contained in FEIS Section 9.4.5 remain valid and have not been reevaluated for this SEIS. The upgrading of site security facilities and the release of Control Zone IV for unconditional use have modified land use restrictions and have resulted in changes in the impacts projected in the FEIS. The upgrading of site security resulted in the denial of 1,200 acres of grazing land that would have supported 18 head of cattle per year. Unconditional release of Control Zone IV resulted in a much smaller impact on hydrocarbon and potash resources than that projected in the FEIS. Between 57 and 71 percent of the distillate, natural gas, crude oil, langbeinite, and sylvite resources projected to be lost will now be available for future extraction. Approximately 50 million tons of total potash resources (langbeinite and sylvite) projected to be lost are now available for extraction.

5.1.4 Air Quality

The air quality evaluations presented in Section 9.3.1 of the FEIS are still considered to be valid. The air quality monitoring program initiated in 1986 has indicated that the air quality in the area of the WIPP meets State and Federal standards except during periods when excessive dust is generated and during a 21-day period when sulfur dioxide levels exceeded standards for a 24-hour average. During two periods in April and May, 1987, measured sulfur dioxide levels at the WIPP site exceeded New Mexico's air quality standards. There were no unusual activities during these periods that would account for these elevated levels and, as these were isolated incidents, tracing their sources was not possible. The dust has been attributed to location of the air sampler near a heavily used dirt road. In 1988, hydrogen sulfide exceeded the standards as the result of paving operations. Also, in December 1988, ozone levels exceeded standards, but the cause has not been identified. In general, construction activities at

the WIPP have had few short-term and no long-term impacts on air quality and none are anticipated from proposed activities at the WIPP site.

5.1.5 Cultural Resources

Two cultural resource evaluations have been performed since 1980 (SEIS Section 4.1), and these evaluations have provided additional insight into the use of the WIPP site area by aboriginal inhabitants. A site discovered during the construction of the railroad spur was excavated and evaluated. No additional impacts to cultural resources at the WIPP site are expected to occur.

5.2 ENVIRONMENTAL IMPACTS OF SEIS PROPOSED ACTION

Impacts discussed in the FEIS for the Proposed Action (continuation of the phased development of the WIPP) are updated and/or modified by the information contained in this subsection and in SEIS Subsection 5.4. The primary areas of modification of impacts are retrieval, handling, and processing of TRU waste at the various facilities (Subsection 5.2.1); transportation from these facilities to the WIPP (Subsection 5.2.2); and radiological and hazardous chemical effects of operations (Subsections 5.2.3 and 5.2.4, respectively). Modifications of impacts in the repository's long-term performance are discussed in Subsection 5.4.

5.2.1 Waste Retrieval, Handling, and Processing at DOE Facilities

This subsection provides information that describes the TRU waste retrieval and processing activities at representative DOE generator/storage facilities. Environmental consequences of these activities are provided for the Idaho National Engineering Laboratory, Savannah River Site, and Hanford Reservation. Additional information is presented in Appendix P of this SEIS, Subsection 9.8 of the FEIS, DOE (1987a, 1988f), and Hoff et al. (1987). This subsection also provides a description of the bin and waste preparation that would occur at the generator/storage facilities prior to the Test Phase (also see Appendices O and P and DOE, 1989d and 1988f).

The DOE believes that the consequences of waste retrieval and processing at the Idaho National Engineering Laboratory, Savannah River Site, and Hanford Reservation generally are representative of the types of impacts that would occur from such activities at all DOE facilities that may eventually transport post-1970 TRU waste to the WIPP. This belief is based on:

- the similarity in retrieval and processing approaches at the various facilities and the nature of retrievable storage among facilities as described herein
- the volume of retrievably stored CH TRU waste at the three DOE facilities described constitutes 83 percent of the total retrievably stored inventory (See Table 3.1)
- the range of the consequences presented for the Idaho National Engineering Laboratory, Hanford Reservation, and Savannah River Site.

In addition, the DOE believes that the environmental consequences of bin and waste preparation have been "bounded" by those analyses conducted for transportation of waste to the WIPP and for waste handling at the WIPP (see Subsections 5.2.2, 5.2.3, and 5.2.4). This belief is based on the following:

- The Test Phase is now likely to use a much lower waste volume (less than 5,000 drum equivalents) than was analyzed for purposes of bounding (88,000 drum equivalents).
- Accident scenario analyses at the WIPP evaluated 1,000 PE-Ci drums, a source term much greater than would occur in the bins (assumed to be approximately 80 PE-Ci).
- Transportation analyses, both incident-free and accidents, for waste shipment to the WIPP during the Test Phase considered 10 percent of the inventory (versus less than 0.5 percent for the bin tests) and maximum curie contents (versus average curie contents during the bin tests), respectively.
- Waste handling, in essence, is similar to the loading of a drum with newly generated waste at the facility.

As noted elsewhere in this SEIS, during the Test Phase the need for additional NEPA documentation based on the new information developed would be determined and prepared, if appropriate. In addition, the DOE will issue another SEIS at the conclusion of the Test Phase and prior to a decision to proceed to the Disposal Phase. Such a SEIS would update the information contained in this subsection and Appendix P for all 10 DOE facilities and would analyze in detail the system-wide impacts (including those from retrieval, handling, processing, and transportation) of disposal of post-1970 TRU waste in the WIPP.

5.2.1.1 Idaho National Engineering Laboratory.

Waste Characteristics and Current Management Methods. Since 1970, contact-handled TRU waste received at the Radioactive Waste Management Complex has been stored at the 56-acre Transuranic Storage Area (TSA), a controlled area surrounded by a security fence. The waste is stored on three asphalt pads known as TSA-1, TSA-2, and TSA-R and in two covered enclosures. Approximately 2.3 million cubic feet of TRU waste is currently stored at the TSA.[a]

Solid TRU waste has been received from the DOE facilities in government-owned ATMX railcars or on commercial truck trailers in Type B shipping containers. The ATMX

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[a] Prior to 1982, TRU waste was defined as having a concentration of alpha-emitting radionuclides greater than 10 nCi/g TRU. In 1982, the definition was changed to include only those wastes with TRU concentrations greater than 100 nCi/g. As a result, about 1/2 of the 2.3 million ft^3 of waste stored at the RWMC is expected to be reclassified as low-level waste, and is not proposed to be shipped to WIPP.

shipments were made under the authority of a special permit issued by the Department of Transportation (DOT Exemption 5948). The waste is contained in 4 x 4 x 7 ft metal boxes with welded lids, 55-gal steel drums with polyethylene liners, and 4 x 5 x 6 ft steel bins. (Earlier, some of the waste placed on the TSA was stored in containers of nonstandard sizes.) The containers are intended to be retrievable, and contamination-free for at least 20 years.

In the past, the drums and boxes were stacked on the TSA pads with boxes around the perimeter and drums in the center. The drums were stacked vertically in layers, with a sheet of 1/2-inch plywood separating each layer. When the stack reached a height of approximately 16 feet, a cover consisting of 5/8-inch plywood, nylon-reinforced polyvinyl sheeting, and 3 feet of soil was emplaced.

Precertified waste (i.e., in compliance with the WIPP WAC) has been received from the generators and is stored in a covered enclosure.

Other current TRU waste operations at the RWMC include the retrieval of drummed waste that has been stored in a covered enclosure located on the TSA-2 pad, and certification of that waste for compliance with the WIPP WAC and appropriate transportation requirements.

This certification takes place in the Stored Waste Examination Pilot Plant (SWEPP) that provides nondestructive examination and assay capabilities to examine TRU waste. The facility contains a Real-Time X-Ray Radiography (RTR) system to examine the contents of both boxes and drums, an assay system to determine fissile and transuranic content, and a container integrity system to assure the waste drums meet DOT metal thickness requirements for Type A containers. In addition, the facility provides capabilities to puncture a drum lid (using a sparkless tool) and install a carbon composite filter to vent any radiolytic-produced gas and provide for pressure equilibrium.

All drums retrieved are vented and examined at this facility. Retrieved waste boxes are also examined using the RTR and the box assay system. Those waste packages that meet the WIPP WAC and transportation requirements are so labeled and stored. Those waste packages that do not meet the WIPP WAC would be further processed at facilities yet to be developed and repackaged before being shipped to the WIPP.

More complete descriptions of the Idaho National Engineering Laboratory, the RWMC, the TRU waste storage and examination facility, and the TRU waste stored on the TSA pads can be found in the Safety Analysis for the Radioactive Waste Management Complex (DOE, 1986) at the Idaho National Engineering Laboratory and the Safety Analysis for the Stored Waste Examination Pilot Plant (SWEPP) (DOE, 1987b).

Environmental Effects of Current Operations. The radiological effects associated with retrieving, examining, venting, and storing TRU waste are presented below. These impacts are discussed for both workers and the general population as a result of normal operations and releases due to potential accidents and violent natural phenomena.

Routine Operations. Measurable exposure to the public or adverse effects on the surrounding environment would not be expected from the extremely small airborne releases experienced during routine operations involving TRU waste at the RWMC. No liquid effluents are expected during routine operations. Releases during normal operations are discussed in annual DOE environmental monitoring reports for the Idaho National Engineering Laboratory (Hoff et al., 1987). In keeping with the ALARA (As Low As Reasonably Achievable) philosophy, the radiological exposures to workers during normal operations are limited by monitoring accumulated personnel dose equivalents and by job preplanning. The maximum radiation exposure on external waste container surfaces is restricted to less than 200 mR/hr. Annual dose equivalents to RWMC personnel including operators, health physics technicians, and supervisors for all RWMC activities, including TRU waste operations, vary from a maximum of 306 mrem to less than 20 mrem. This is well below the established DOE occupational exposure limit of 5 rem per year (DOE, 1988a).

Accident Conditions. Safety documentation prepared for the current operations of the RWMC complex, which includes all TRU operations, evaluates the dose commitments and risks associated with potential operational accidents (e.g., fires, explosions, dropped containers), as well as those associated with potential natural disasters (e.g., earthquakes, volcanoes, lightning) (Passmore, 1986). The projected consequences and risks of the dominant accident scenarios for the general public and workers are summarized for the SEIS in Tables 5.2 and 5.3, respectively.

The maximum exposure to an individual member of the public is shown in Table 5.2 to be 2×10^{-2} rem committed whole-body dose equivalent. This exposure is associated with the occurrence of a tornado with 280 mile per hour winds, which has an extremely low probability of occurrence at the Idaho National Engineering Laboratory. The highest population exposure is also associated with the tornado and results in a collective dose equivalent of 1 person-rem. The excess risk to the total exposed population would be 2.8×10^{-4} excess cancer fatalities based on a multiplier of 2.8×10^{-4} latent cancer fatalities/person-rem.

Table 5.3 indicates that the highest exposure to the maximally exposed worker is 0.7 rem, resulting from a fire in the air support weather shield. The risks of excess cancer to both the workers and average members of the public are presented in Table 5.4.

Methods for Retrieving and Handling Waste. Several operations would be involved in removing the waste and preparing it for shipment to the WIPP: retrieving waste from earthen-covered cells and potential processing and packaging of the waste to meet current WIPP WAC and transportation criteria. The FEIS evaluated several options for each operation.

TABLE 5.2 Summary of radiological consequences to the public from accidental or abnormal releases during RWMC/SWEPP operations with stored TRU waste[a]

Event	Release fraction	Event frequency yr^{-1}	Maximally Exposed Individual: Committed Dose Equivalent (rem)[b] Body	Bone	Lung	Population: Collective Dose Equivalent (person-rem)[b] Body	Bone	Lung
Tornado	5×10^{-4}	1×10^{-7}	2×10^{-2}[d]	4×10^{0}[d]	5×10^{-1}[d]	1×10^{0}	2×10^{3}	4×10^{3}
Earthquake[c]	8×10^{-8}	2×10^{-4}	2×10^{-7}	3×10^{-4}	4×10^{-4}	3×10^{-4}	4×10^{-1}	8×10^{-1}
Fire in ASWS/C&S	8×10^{-7}	1×10^{-3}	1×10^{-6}	3×10^{-3}	4×10^{-3}	3×10^{-3}	4×10^{0}	7×10^{0}
Breached container	8×10^{-8}	6×10^{-4}	2×10^{-8}	3×10^{-5}	4×10^{-5}	3×10^{-5}	4×10^{-2}	8×10^{-2}
Explosion	5×10^{-7}	1×10^{-4}	2×10^{-3}[d]	3×10^{-2}[d]	2×10^{-2}[d]	2×10^{-4}	2×10^{-1}	4×10^{-1}

[a] Letter updating tables from WM-PD-86-011-Rev 2 (DOE, 1989a).

[b] Exposure calculated using ICRP-2 dosimetry and methodology (Passmore, 1986).

[c] Release due to damaged containers.

[d] The maximum annual dose equivalent and not the committed dose equivalent is stated.

TABLE 5.3 Summary of radiological consequences to the maximally exposed worker from accidental or abnormal events during RWMC/SWEPP operations with stored TRU waste[a]

Event	Event frequency (yr^{-1})	Dose equivalent to maximally exposed worker (rem)[b]					
		Inside facility			Outside facility		
		Body	Bone	Lung	Body	Bone	Lung
Earthquake[c]	2×10^{-4}	1×10^{-1}	4×10^{0}	6×10^{0}	8×10^{-5}	1×10^{-1}	2×10^{-1}
Fire in ASWS/C&S	1×10^{-3}	7×10^{-1}	2×10^{1}	6×10^{1}	4×10^{-4}	8×10^{-1}	1×10^{0}
Breached container	6×10^{-4}	1×10^{-2}	4×10^{1}	6×10^{1}	8×10^{-6}	1×10^{-2}	2×10^{-2}
Explosion	1×10^{-4}	2×10^{-3}	7×10^{-2}	4×10^{-3}	1×10^{-3}	4×10^{-2}	1×10^{-3}
Lightning strike	4×10^{-6}	1×10^{-3}	2×10^{0}	4×10^{0}	1×10^{-6}	1×10^{-3}	2×10^{-3}

[a] Letter updating tables from WM-PD-86-011-Rev 2 (DOE, 1989a).

[b] Exposure calculated using ICRP-2 dosimetry and methodology (Passmore, 1986).

[c] Release due to damaged container.

TABLE 5.4 Excess cancer risks due to accidents associated with RWMC/SWEPP operations with TRU stored waste

Event	Excess Cancer Risk[a,b,c]		
	Maximally exposed individual	Average member of population[d]	Maximally exposed worker[e]
Tornado	6×10^{-6}	2×10^{-9}	nc[f]
Earthquake	6×10^{-11}	7×10^{-13}	3×10^{-5}
Fire in ASWS/CS	3×10^{-10}	7×10^{-12}	2×10^{-4}
Breached container	6×10^{-12}	7×10^{-14}	3×10^{-6}
Explosion	6×10^{-7}	4×10^{-13}	6×10^{-7}

[a] Health risks are expressed as the probability of an individual contracting a fatal cancer during his/her lifetime as a result of RWMC/SWEPP related activities.

[b] Risk of contracting fatal cancer: 2.8×10^{-4} fatalities/person-rem (BEIR, 1980).

[c] Health effects risk estimates for genetic effects would be somewhat less than the numbers presented in the table for cancer fatality risks as discussed in Appendix N.

[d] Risk to an average member of the population is the product of the collective population exposure (Table 5.2) by 2.8×10^{-4} fatalities/person-rem divided by an estimated population of 129,000.

[e] Risk based on exposure within the facility (Table 5.3).

[f] Not calculated.

Three methods of retrieving waste containers were considered: 1) manual handling by the operators; 2) handling by means of operator-controlled equipment; and 3) handling by means of remotely controlled equipment. A combination of the first two methods is currently being performed for retrieval of drummed waste located at the TSA-2 pad and would likely be used for the remaining post-1970 TRU waste.

Four confinement methods for waste retrieval were considered: 1) open-air retrieval (no confinement); 2) the use of an inflatable fabric shield to protect against the weather; 3) the use of a movable, solid-frame structure operating at ambient pressure; and 4) the use of a movable or nonmovable, solid-frame structure operating at subatmospheric pressure. The last method is the only one that provides positive control against the possible release of contamination.

Four potential processing options were also considered in the FEIS: 1) shipping as is, 2) overpacking, 3) repackaging only, and 4) treatment and packaging. A slagging pyrolysis incineration (SPI) process was proposed for waste treatment and was analyzed in detail in the FEIS. Incineration was the selected processing technology because it was anticipated that free liquid and combustible limitations in the WIPP WAC would make some of the stored waste unacceptable. Waste feed to the SPI was to be blended with glassforming compounds (soil) so the noncombustible ash would be melted at the incineration temperature and form a glass-like slag with low leachability. The molten slag was to be packaged in steel drums. Since 1980, this process was evaluated on an experimental basis and was proven inadequate for development for reliable treatment of stored TRU waste (Tait, 1983). No further DOE development of the process has occurred.

The following subsections discuss conceptual operations of facilities that may be proposed for the retrieval and processing/packaging of TRU waste at the Idaho National Engineering Laboratory. At such time that specific facilities are proposed, the appropriate NEPA documentation will be prepared for these new facilities and operations.

Retrieval Building and Operations. The retrieval building currently under conceptual design would be either a mobile or large, fixed single-walled structure. Subatmospheric pressure would be maintained inside to prevent the escape of contaminants during retrieval operations. The ventilation system would include roughing filters and a bank of high-efficiency particulate air (HEPA) filters, for an estimated overall decontamination factor of 1,000.

Prior to erection of the building over the retrieval area, most of the soil cover may be removed. After the building is in place, the remainder of the soil, the polyvinyl sheeting, and the plywood cover would be removed to expose the waste containers and permit retrieval.

Waste containers would be inventoried and examined to confirm their integrity. Any breached containers would be placed in a waste transfer container and loaded into a transfer vehicle. Forklifts would remove the intact containers from the stacks and place them into the transfer vehicle. The waste would be transferred from the retrieval building to drum venting and examining facilities. Following venting and examining, the

container would be placed in storage modules for eventual transfer to a processing facility or a transporter loading facility. All transfers would be made using the controlled roadways within the RWMC.

Processing to Meet WIPP WAC. Facilities are also being conceptually designed to provide for the storage, treatment, and repackaging of the retrieved waste to meet the WIPP WAC. Noncertifiable drums and boxes would be segregated, based on nondestructive examination, into waste packages containing large metallic components, packages containing liquids or respirable/dispersible particulates, and oversize packages that do not meet transportation requirements. Treatment processes under consideration include size reduction using mechanical and plasma arc cutting to size-reduce metallic components, immobilization to stabilize free liquids or respirable/dispersible particulates, and shredding/compaction to shred and repackage boxed waste.

These facilities would be designed to ensure two levels of containment (in addition to the waste container) for all waste processing and repackaging areas. The ventilation system would be designed to maintain progressively lower pressures between the outside atmosphere and the waste processing areas. All air removed by the ventilation systems would pass through appropriate HEPA filtration systems for an estimated overall decontamination factor of 1,000.

Prior to construction of these facilities under conceptual design, NEPA documentation will be prepared to analyze the impacts of the proposed retrieval, treatment, and repackaging activities at the Idaho National Engineering Laboratory; alternatives would be considered.

In addition, a potential treatment facility is being developed at the Idaho National Engineering Laboratory, the Process Experimental Pilot Plant (PREPP). The PREPP is a research and development treatment facility designed to demonstrate the efficacy of a process to certify certain TRU waste. Eventually the PREPP treatment technology may be used in a production facility to certify (to the WIPP Waste Acceptance Criteria) a limited volume of TRU waste in retrievable storage. The PREPP is an incineration-based technology developed subsequent to the Slagging Pyrolysis incinerator (SPI) technology discussed in Subsection 9.8 of the FEIS. A brief description of the PREPP process is provided in Appendix P.

5.2.1.2 Savannah River Site. Stored TRU waste at the Savannah River Site is in retrievable storage on concrete pads or buried in shallow trenches. It is contained in concrete and steel boxes, concrete culverts, and galvanized steel drums covered with 4 ft of earth or tornado netting (in use since 1985).

The soil cover would be removed from the stored waste pads by earth-moving equipment and with the remotely operated, HEPA-filtered soil vacuum. Drums would be removed using a shielded lifting canister. Large steel boxes and concrete culverts would be lifted from the pads and placed directly on a transport trailer for shipment to the TRU Waste Processing Facility building.

Waste containers would be received at the TRU Waste Processing Facility through an airlock into a high bay storage and opening area. The TRU Waste Processing Facility

would be used to vent, purge, x-ray, and assay the storage containers; size-reduce the large waste not suitable for shipment; solidify free liquids, resins, and sludge; and repackage the waste to meet the current WIPP WAC. Large steel boxes would be opened in this area, and plywood boxes within the large steel boxes would be removed to be processed individually. Culverts would be opened remotely, and drums would be removed and placed into a cell where they would be vented, purged with inert gas, and fitted with a filter vent before going to the verification area. Any gases vented from the drums would pass through the building exhaust system. Each container would then be x-rayed to assist in verifying compliance with the WAC.

After being x-rayed, containers not conforming to the WAC would pass through an airlock into the remote waste-preparation cell. Drums and other pieces of equipment may be placed in a shredder for size-reduction. Some smaller equipment would be placed directly in a drum overpack for removal using bagless transfer systems. Waste forms segregated as requiring additional processing, such as HEPA filters and respirable fines, would be stabilized or solidified in the TRU Waste Processing Facility to meet the WAC. Certified drums of TRU waste would be put in retrievable storage pending shipment to the WIPP.

The consequences of potential accidents occurring during retrieval and processing are summarized in Tables 5.5 and 5.6.

5.2.1.3 Hanford Reservation. CH TRU waste is in retrievable storage trenches and aboveground buildings. Waste containers would be retrieved in an open environment without releasing airborne radioactivity. The earth overburden would be removed using conventional equipment or hand digging as required. Once the overburden is removed, the packaged waste would be removed by a forklift or crane.

Retrievably stored CH TRU waste would be removed and transferred to a Waste Receiving and Processing facility. Waste not directly certifiable would be processed within the proposed Waste Receiving and Processing facility to produce waste packages that would meet the current WAC.

The major functions of the Waste Receiving and Processing facility would be: 1) to provide for examination, processing, packaging, and certification of retrievably stored CH TRU waste, and 2) to provide for examination and certification of newly generated CH TRU waste for repository disposal.

The Waste Receiving and Processing facility is being designed to support examination and certification of CH TRU waste for disposal at the WIPP and is scheduled to be constructed during the 1990s. Processing and packaging capabilities for CH TRU waste in retrievable storage would also be provided in the Waste Receiving and Processing facility. Retrievably stored and newly generated waste would be inspected and certified to meet the WAC.

Waste process systems being considered include waste package inspection, assaying, repackaging, size reduction, compaction, sorting, shredding, and waste immobilization in grout. Waste would be incinerated as an additional process step between shredding and grouting, if appropriate. The consequences of Waste Retrieval and Processing operations are shown in Tables 5.7 and 5.8.

TABLE 5.5 Summary of consequences from postulated accidents during retrieval at the Savannah River Site[a]

Accident	Curies released	Effective dose equivalent: On-site population (person-rem)	Effective dose equivalent: Off-site population (person-rem)	Effective dose equivalent: Offsite maximally exposed individual (mrem)
Winds[b]				
100 mph	2.1×10^{-2}	1.6×10^{-1}	4.4	6.3×10^{-2}
> 150 mph	4.2×10^{-2}	2.2×10^{-1}	6.3	7.3×10^{-2}
Tornado				
113-157 mph	2.5×10^{-2}	9.3	1.6×10^{1}	1.3×10^{-2}
158-206 mph	5.3×10^{-2}	2.1×10^{1}	3.5×10^{1}	2.7
Fire				
Drum in culvert	1.7	9.3×10^{3}	2.0×10^{4}	4.4×10^{3}
Drum on pad	5.0×10^{-3}	2.8×10^{1}	6.1×10^{1}	1.3×10^{1}
Drum rupture				
Internal pressure	5.0×10^{-3}	2.8×10^{1}	6.1×10^{1}	1.3×10^{1}
External pressure	5.0×10^{-5}	2.8×10^{-1}	6.1×10^{-1}	1.3×10^{-1}

[a] Estimated from the analysis of potential burial ground accidents reported in DPSTSA-200-10, Supp. 8.

[b] Straight winds.

TABLE 5.6 Summary of consequences from postulated accidents during retrieval in the TRU Waste Processing Facility at the Savannah River Site[a]

Accident	Curies released		Effective dose equivalent		
	Pu-238	Pu-239	On-site population (person-rem)	Off-site population (person-rem)	Offsite maximum individual (mrem)
Winds[b]					
100-150 mph	4.3	4.7×10^{-2}	5.1×10^{1}	7.3×10^{2}	1.1×10^{1}
> 150 mph	8.8	9.5×10^{-2}	7.3×10^{1}	1.1×10^{3}	1.8×10^{1}
Tornado					
100-200 mph	5.2	5.7×10^{-2}	1.9×10^{3}	2.8×10^{3}	2.5×10^{2}
> 200 mph	4.4×10^{1}	4.7×10^{-1}	1.5×10^{4}	2.3×10^{4}	2.0×10^{3}
Earthquakes					
0.09-0.2 g	4.3×10^{-2}	5.0×10^{-4}	3.4×10^{2}	4.3×10^{2}	1.1×10^{2}
Vehicle crash	2.2×10^{-2}	2.4×10^{-4}	1.7×10^{2}	2.1×10^{2}	5.5×10^{1}
Fire	8.7×10^{-3}	9.5×10^{-5}	7.3×10^{1}	9.3×10^{1}	2.5×10^{1}
Drum rupture					
Internal pressure	4.3×10^{-3}	4.7×10^{-5}	3.4×10^{1}	4.2×10^{1}	1.1×10^{1}
External pressure	4.3×10^{-5}	4.7×10^{-5}	3.5×10^{-1}	4.3×10^{-1}	1.1×10^{-1}

[a] Estimated from the analysis of potential ETWAF/WCF accidents reported in DPSTSA-200-17, Rev. 1.

[b] Straight winds.

TABLE 5.7 Population total-body dose commitments (person-rem) from the processing of retrievably stored and newly generated CH TRU waste at the Hanford Reservation Waste Retrieval and Processing Facility

Pathway	Exposure period	
	1 year	70 years
Air submersion	5.0×10^{-11}	9.0×10^{-10}
Inhalation	1.2×10^{-5}	2.4×10^{-4}
Terrestrial (air paths)	2.0×10^{-7}	4.0×10^{-5}
Total doses	1.2×10^{-5}	2.8×10^{-4}

TABLE 5.8 Maximum individual total-body dose commitments (rem) from the processing of retrievably stored and newly generated CH TRU waste at the Hanford Reservation Waste Retrieval and Processing Facility

Pathway	Exposure period	
	1 year	70 years
Air submersion	3.7×10^{-16}	7.3×10^{-15}
Inhalation	9.7×10^{-11}	2.1×10^{-9}
Terrestrial (air paths)	3.6×10^{-12}	7.4×10^{-10}
Total doses	1.0×10^{-10}	2.9×10^{-9}

Special equipment would be used to recover the RH TRU waste in caissons. A recovery building would be positioned over the first caisson row and would contain a remotely operated manipulator and associated equipment. The retrieval operations would be controlled remotely from an auxiliary control room. A grappler housing equipped with a telescoping articulated boom would retrieve the caisson waste stored in 1-gal and 5-gal containers. An airlock and conveyor system would be used to transfer the remotely handled cask containing the retrieved caisson waste. This cask would be remotely sealed and decontaminated before placement on a truck.

A small amount of retrievably stored and newly generated RH TRU waste would also require processing. This waste may be routed to a Special Handling and Packaging Facility designed to process RH TRU waste (not in the Waste Receiving and Processing facility). This facility would be functionally similar to the Waste Receiving and Processing facility, and its operations would include specific processes required to immobilize and package RH solid waste.

5.2.1.4 Los Alamos National Laboratory. Since 1971, TRU waste has been packaged and stored in either subsurface trenches or aboveground earth berms at the waste burial site. Two types of packaging have generally been used, 55-gal steel drums (sealed and coated with bituminous corrosion protection material) and plywood crates (sealed and coated with fiberglass-reinforced polyester). Plywood storage crate sizes vary considerably, with a maximum length of approximately 30 ft.

Retrieval would require heavy earth-moving equipment and a crane capable of about a 60-ft reach to remove the overburden. A small rubber track front-end loader would assist in the final stages of retrieval. Final excavation would require manual labor to ensure that no packages are breached. Waste would then be removed using the crane for larger crates and a forklift for smaller crates and drums.

Newly generated certified waste would be stored aboveground on an asphalt pad and protected from the elements by plywood and a plastic cover topped with at least 3 feet of earth, much in the same manner in which waste has been retrievably stored since 1971.

The TRU waste facilities include:

- Existing storage facilities
- TRU Waste Size Reduction Facility
- TRU Contaminated Solid Waste Treatment and Development Facility
- TRU Waste Preparation Facility
- TRU Waste Nondestructive Analysis and Examination Facility
- TRU Waste Transportation Facility
- TRU Waste Corrugated Metal Pipe Saw-Processing Facilities

- Other related facilities: liquid waste treatment plant.

The TRU waste facilities would be capable of handling not only newly generated TRU waste but also stored waste and would, either individually or in conjunction with one another, produce certified TRU waste. The Size Reduction facility and the Solid Waste Treatment and Development facility are existing, online facilities that would be modified. Radioactive-contaminated liquid waste would be treated at the existing liquid waste treatment plant, which would require no modification.

5.2.1.5 Oak Ridge National Laboratory. Retrievably stored waste is packaged in stainless steel drums, mild iron drums, and wooden boxes. Newly generated TRU waste is packaged in stainless steel drums at the point of generation and is transported within the Oak Ridge National Laboratory site boundary to the TRU waste storage area.

No special facilities are anticipated to be required for retrieval of contact-handled, retrievably stored and newly generated TRU solid waste. The stored CH TRU waste containers would be removed from this area, using normal material-handling methods.

From the staging or interim storage area, retrievably-stored waste, along with newly generated CH waste, would be moved to the Waste Examination Assay Facility. Containers of waste would be nondestructively examined and assayed to determine whether they meet the WAC.

Waste not meeting the WAC would be repackaged. The material that causes a drum to fail certification (generally free liquids or compressed gases) would be removed and disposed of in an appropriate manner. Fine particle materials, in quantities greater than the WAC allow, would be immobilized and repackaged for shipment to the WIPP. Then the drum would be repackaged, sealed, and returned to the assay facility for final certification.

5.2.1.6 Rocky Flats Plant. The Rocky Flats Plant Supercompaction and Repackaging Facility and TRU Waste Shredder are being proposed to process solid waste which is newly generated during routine production operations, maintenance activities, and laboratory support operations at the Rocky Flats Plant. Waste may be processed in permitted storage if appropriate. The Colorado Department of Health currently recognizes eight permitted storage areas at the Rocky Flats Plant for TRU mixed waste. The areas differ in size for a total permitted storage capacity of 1,601 yd^3. The storage units are within existing structures having concrete floors covered with epoxy paint and fenced areas within the buildings, which allow segregation of the storage facility from adjacent operations.

Two categories of waste would be processed: soft or combustible waste, and hard or noncombustible waste. Combustible waste includes such items as paper and plastic. Noncombustible waste includes miscellaneous metals, piping, motors, glass, Raschig rings, process filters, and high efficiency particulate air (HEPA) filters. The waste types are separated into designated drums at the point of generation, and separation is maintained throughout the waste management operations.

Hard waste packaged in 35-gal steel drums would be directly supercompacted (drum and all) into "pucks", and the pucks would be loaded into 55-gal steel drums for final disposal. Bags of soft waste, initially packaged in 55-gal drums, would be unpacked and precompacted into 35-gal drums, and then the 35-gal drums would be supercompacted as described above.

The Rocky Flats Plant TRU Waste Shredder would be used to process discarded graphite molds and filters. Approximately 80 percent of the waste to be processed in the TRU Waste Shredder would be filters. The remaining 20 percent would be graphite molds.

The graphite molds would be crushed in the shredder. Approximately 10 to 20 55-gal drums of classified graphite molds would be processed in one month. Each drum would contain approximately 100 to 150 pounds of molds. Weighing approximately 20 pounds each, the molds would be individually wrapped in heavy vinyl bags inside the drums. They would be removed from the drums prior to shredding. Once processed, they would be considered TRU waste.

The filter waste that would be shredded includes HEPA filters and process filters. Approximately 30 to 70 55-gal drums of combined filter types would be processed in one month. The HEPA filters with their frames would be individually wrapped in heavy vinyl and contained in cardboard boxes. The process filters would be contained in 55-gal drums. The filters would be shredded for volume reduction and packaged in 35-gal steel drums for supercompaction in the Supercompaction and Repackaging Facility as hard waste.

5.2.1.7 Bin Test Preparation. During the Test Phase, the DOE proposes to operate the WIPP with limited amounts of waste. For this SEIS, it is assumed that the maximum amount of TRU waste that would be used during the Test Phase is 10 percent of the TRU waste (by volume) that could ultimately be emplaced at the WIPP. It is also assumed that waste would be shipped from all 10 facilities, although it is now likely that only waste from the Rocky Flats Plant and Idaho National Engineering Laboratory would be used during the initial phase of the proposed Test Phase.

The bin-scale tests involve testing in multiple large, instrumented metal "bins" with specially prepared TRU waste and appropriate material additives. The "prepared" waste includes up to 6 drum-volume-equivalents of a specific type of representative CH TRU waste with added backfill materials (including salt), metal corrodants (mild steel wire mesh), and brine (to be injected at WIPP). Within each individual test bin there will be a specific type of TRU waste, either noncompacted or compacted. Plastic bags encapsulating this waste will be "prebreached"; that is, the bags will be sliced or slashed, or the waste itself will be shredded. This "prebreaching" permits contact between, and interactions of, the waste with other added components within the bin, and within a time frame shorter than expected in the repository. Additional details regarding the bin-scale tests are presented in Appendix O.

Preparation of the waste and bins would occur at the generator facilities. The program design currently includes the following assumptions with regard to waste packaging and transportation.

Two additions would be made to the preinstrumented bin before the waste would be placed in the test bin. First, about a half-drum volume of backfill material would be placed in the bottom of the test bin. Second, about 6 drum-equivalents of bare, unpainted steel (mild steel wire mesh) would be placed along the bottom and side walls of the bin. The bins would then be remotely filled with waste.

Prior to bin loading, a waste characterization effort would be undertaken. Although this characterization effort is evolving, it is currently anticipated that the volatile organic compounds in the headspace of each drum would be sampled and its constituents' concentrations determined. After gas sampling, each drum would be opened and its contents qualitatively assessed by visual inspection (i.e., relative evaluation of waste type and form). In addition, for processed sludges only, a sample would be collected from each drum and would be subjected to a complete chemical and radiological analysis by recognized protocols. After sampling, waste would be placed in the bins.

After the waste is placed in the bins, another half-drum volume of backfill material would be sprinkled on top of the waste materials. The mated bin-lid and liner-lid combination would then be attached to the bin and sealed. The filled bin would be checked for surface contamination and, if necessary, decontaminated following standard procedures of the generator facility.

The waste-filled test bins would be inserted into standard waste boxes (SWB) for transportation to the WIPP. The upper gas valves on the test bins (with HEPA filters) would be left in the open, gas-release position during transportation. Therefore, any gases vented would also be filtered through the redundant HEPA filter of the SWB. The SWBs would be loaded into the TRUPACT-II transportation containers and trucked to the WIPP. Waste bins would be removed from the SWBs in the WIPP underground, just prior to emplacement; brine would be added as needed. The procedures for loading and assembling TRUPACT-IIs are presented in Appendix L.

5.2.2 Transportation

This subsection examines the potential environmental effects associated with the transportation of TRU waste from the generator and storage facilities to the WIPP. The FEIS assessed the impacts of transporting TRU waste to the WIPP from the Idaho National Engineering Laboratory in Idaho and the Rocky Flats Plant in Colorado. This SEIS estimates the cumulative risks associated with potential TRU waste shipments from 10 generator and storage facilities, as discussed in Subsection 3.1.1.3.

The radiation exposure rate at the surface of the TRUPACT-II container was used to estimate the radiation dose equivalent to the population along the transportation routes to the WIPP. Since the TRUPACT-II is not vented, exposure to the hazardous chemical component of the TRU waste would not occur during routine transportation. Radiological risks to the public were calculated based on a full range of transportation accident scenarios and their probabilities of occurrence. A "bounding case" accident involving TRUPACT-II containers has been developed for completeness and to provide an upper-bound assessment of impacts. Evaluation of this accident provides maximum estimates of radiological and hazardous chemical risks (Subsections 5.2.2.1 and 5.2.2.2, respectively).

This assessment also addresses the risks of traffic accidents and vehicle emissions associated with the transportation of TRU waste to the WIPP. Risks related to vehicle emissions were estimated for rail and truck from the number of miles traveled to the WIPP. During preparation of this SEIS, DOE requested state-specific data from 23 States that would be affected by TRU waste transportation. The following information was requested: total miles traveled, the number of accidents involving property damage, injuries, fatalities, and other information concerning the preferred shipping routes. Data were also requested concerning road segments of concern. State-specific data received were used in the impact assessments presented in Subsection 5.2.2.3 and are summarized in Appendix D.

5.2.2.1 Radiological Risk Assessment for Transportation. Radiological risks to occupationally exposed transportation workers (e.g., truck drivers, train operators), the general public, and the environment are assessed along transportation corridors from the generator and storage facilities to the WIPP. The assessment utilizes information on radiological characteristics of TRU waste as discussed in SEIS Appendix B. Radiological exposures potentially received by the public from routine transportation and from transportation accidents are provided below.

This SEIS provides risk estimates developed in response to more complete characterization of the TRU waste inventory, changes in the transportation routes and modes, and modifications to the dose assessment methodology from that assumed or employed in the FEIS.

The FEIS reported transportation impacts in terms of a radiation dose to an individual or population. Dose commitments were calculated for the whole body, lungs, and bone. The SEIS expresses radiation exposure in terms of committed effective dose equivalent and risk in terms of excess lifetime cancer risk. In both instances, the dose considered is that which occurs over the 50-year period following exposure. Direct

comparisons of doses and risks reported in the FEIS to those reported in this SEIS cannot be made because of the differences in the assessment methodologies and the method of expressing dose. The SEIS estimates are based on updated knowledge of the waste and improved assessment models and provide a more current estimate of transportation risks.

RADTRAN, a computer code (see Appendix D), was used in the FEIS to estimate radiation doses associated with normal or "routine" transportation of TRU waste to the WIPP. The FEIS used a modified version of the computer code AIRDOS-II (Moore, 1977) to calculate radiation doses for specific transportation accident scenarios. A specific, "most conservative" accident scenario was developed to represent an upper bound for an accident-induced release during waste transport. AIRDOS-II was then used to compute dose consequences to the public, assuming stable meteorological conditions to maximize the resulting dose consequences. The accident analysis results were reported as dose consequences to an individual and to various population groups. An estimate was also made of the likelihood of such accidents.

In this SEIS, the radiological risks of transportation have been assessed using a modification of RADTRAN, a more recent version of the RADTRAN code that considers routine and accident situations. As discussed in Appendix D, the RADTRAN model has been previously used and accepted by the Nuclear Regulatory Commission (NRC, 1977) and the Department of Energy (DOE, 1980).

In the RADTRAN models, risks are not based on specific accidents but on the likelihood and consequence of accidents of various severities, with more severe accidents having a higher release fraction (i.e., amount of waste that is released to the environment) but lower probability of occurrence. The fractions of material released vary as a function of accident severity category. The model provides a probability weighted estimate of cumulative risk rather than specific dose calculations for individual accident scenarios. Further discussion of the risk calculation using the RADTRAN code is provided in SEIS Appendix D.3.

Even though accidents of different severity categories are already included in the RADTRAN analysis, specific "bounding case" transportation accident scenarios have been developed for the SEIS. The impact analysis was conducted to provide an upper-bound impact that could occur as a result of a severe accident involving transport of TRUPACT-II containers or RH casks. These scenarios were analyzed separately using the RADTRAN and AIRDOS models.

The FEIS analysis assumed that 25 percent of the TRU waste would be shipped to the WIPP by truck and 75 percent by rail. In this SEIS, even though the preferred transport mode is truck, rail transportation impacts are analyzed in the event rail is utilized in the future. Therefore, this SEIS analyzes two cumulative transportation scenarios: 1) a 100 percent truck, and 2) a maximum rail transport case for waste transport from the generator and storage facilities. The maximum rail transport scenario consists of rail transport from eight of the 10 generator and storage facilities and truck transport from the two facilities (Nevada Test Site and Los Alamos National Laboratory) that do not currently have rail access. These two scenarios are projected to bound potential transportation impacts.

Routine Exposures from Transportation Activities. As discussed above, the FEIS used the RADTRAN code to estimate the radiation doses associated with incident free (routine) transportation of TRU waste to the WIPP. This SEIS uses a modification of the RADTRAN code to calculate routine doses to transportation workers, including truck drivers, and to members of the public on and along the route during transport and stops. Tables D.3.5, D.3.6, and D.3.7 in Appendix D.3 summarize key input parameters for the RADTRAN code. In general, risk assessment methodologies and waste characterization data have improved since publication of the FEIS, and provide more representative estimates than the FEIS analyses.

The only potential radiation exposure during routine transportation activities will be from direct radiation which penetrates the TRUPACT-II container or RH cask. Direct radiation exposures to truck drivers, to members of the public driving alongside a waste shipment, to the roadside population, and to people in the parking lots where stops are made, are estimated. Table 5.9 provides the potential number of shipments from each location to the WIPP and the radiological exposure associated with shipments for the Proposed Action.

Annual exposures from waste transport based on projected inventory and current shipping plans for the Proposed Action are shown in Tables 5.10 and 5.11 (for Alternative Action, see Tables 5.47 and 5.48).

TABLE 5.9 Projected TRU waste shipments and radiological exposure from waste shipments to the WIPP[a]

	CH waste							
	Total shipments[b]		Incident-free Exposures per shipment[c] (person-rem)				Accidents Exposures per shipment (person-rem)	
			Truck		Rail[e]		Truck	Rail
Facility	100% Truck	Maximum Rail[d]	Occupational	Public	Occupational	Public	Public	Public
Idaho National Engineering Laboratory	4046	2023	5.0×10^{-2}	2.0×10^{-2}	2.9×10^{-4}	3.0×10^{-2}	7.9×10^{-4}	5.7×10^{-4}
Rocky Flats Plant	7608	3804	4.0×10^{-2}	1.0×10^{-2}	2.7×10^{-4}	2.0×10^{-2}	2.0×10^{-4}	1.9×10^{-4}
Hanford Reservation	3103	1552	3.9×10^{-2}	2.3×10^{-2}	2.6×10^{-4}	4.0×10^{-2}	9.9×10^{-4}	8.9×10^{-4}
Savannah River Site	2640	1320	1.4×10^{-1}	7.0×10^{-2}	8.4×10^{-4}	1.2×10^{-1}	4.2×10^{-2}	4.0×10^{-2}
Los Alamos National Laboratory[f]	2065	---	2.8×10^{-2}	8.0×10^{-3}	---	---	1.3×10^{-3}	---
Oak Ridge National Laboratory	228	114	1.3×10^{-1}	2.0×10^{-1}	2.1×10^{-3}	2.0×10^{-1}	4.4×10^{-3}	4.2×10^{-3}
Nevada Test Site[f]	80	---	5.0×10^{-2}	2.0×10^{-2}	---	---	8.9×10^{-6}	---
Argonne National Laboratory - East	14	7	1.3×10^{-1}	1.4×10^{-1}	1.8×10^{-3}	1.9×10^{-1}	4.9×10^{-4}	3.5×10^{-4}
Lawrence Livermore National Laboratory	969	485	1.7×10^{-2}	9.0×10^{-3}	1.2×10^{-4}	1.6×10^{-2}	1.9×10^{-4}	2.9×10^{-4}
Mound Laboratory	150	75	1.9×10^{-2}	9.0×10^{-3}	1.1×10^{-4}	1.4×10^{-2}	2.8×10^{-5}	5.4×10^{-7}
TOTAL	20903	9380						

TABLE 5.9 Concluded

	RH waste							
	Total shipments		Incident-free Exposures per shipment (person-rem)				Accidents Exposures per shipment (person-rem)	
			Truck		Rail[e]		Truck	Rail
	100% Truck	Maximum Rail[d]	Occupational	Public	Occupational	Public	Public	Public
Idaho National Engineering Laboratory	487	244	1.0×10^{-1}	8.0×10^{-2}	1.3×10^{-3}	1.3×10^{-1}	1.6×10^{-3}	1.3×10^{-3}
Hanford Reservation	2470	1235	1.7×10^{-1}	3.3×10^{-1}	3.5×10^{-3}	2.9×10^{-1}	4.3×10^{-5}	4.4×10^{-5}
Los Alamos National Laboratory[f]	101	—	2.8×10^{-2}	1.2×10^{-2}	—	—	3.1×10^{-6}	—
Oak Ridge National Laboratory	4605	2303	6.3×10^{-2}	4.4×10^{-2}	7.7×10^{-4}	7.4×10^{-2}	4.8×10^{-6}	5.2×10^{-6}
Argonne National Laboratory - East	300	150	5.0×10^{-2}	4.0×10^{-2}	5.5×10^{-4}	5.0×10^{-2}	6.4×10^{-6}	5.2×10^{-6}
TOTAL	7963	3932						

[a] Calculations based on three TRUPACT-IIs or one RH canister per truck and six TRUPACT-IIs or two RH canisters per railcar.

[b] Shipments calculated from drum volume of 0.2 m^3x14 drums/TRUPACT II.

[c] Risks per shipment are a function of the Transport Index (see Appendix D).

[d] Maximum rail shipments under either alternative; for the Proposed Action, the shipments during the Test Phase would be by truck.

[e] Rail occupational risks include the impact of DOT inspection activities.

[f] No rail transport; for calculation of total shipments, maximum rail, the number of truck shipments from facilities without rail access are included for CH waste and RH waste.

TABLE 5.10 Annual radiological exposures (person-rem) for CH TRU Proposed Action waste shipments to the WIPP[a]

	5-Yr Test Phase[b]		20-Yr Disposal Phase			
	100% Truck		100% Truck		Maximum Rail	
Facility	Occupational[c]	Public[d]	Occupational	Public	Occupational	Public
Idaho National Engineering Laboratory						
Normal	4.0×10^{0}	1.6×10^{0}	9.0×10^{0}	3.6×10^{0}	2.6×10^{-2}	2.8×10^{0}
Accident		6.4×10^{-2}		1.4×10^{-1}		5.0×10^{-2}
Rocky Flats Plant						
Normal	6.0×10^{0}	1.5×10^{0}	1.4×10^{1}	3.4×10^{0}	4.5×10^{-2}	3.4×10^{0}
Accident		3.0×10^{-2}		7.0×10^{-2}		3.2×10^{-2}
Hanford Reservation						
Normal	2.4×10^{0}	1.4×10^{0}	5.5×10^{0}	3.2×10^{0}	1.8×10^{-2}	2.8×10^{0}
Accident		6.2×10^{-2}		1.4×10^{-1}		6.0×10^{-2}
Savannah River Site						
Normal	7.4×10^{0}	3.6×10^{0}	1.6×10^{1}	8.5×10^{0}	5.0×10^{-2}	7.0×10^{0}
Accident		2.2×10^{0}		5.0×10^{0}		2.4×10^{0}
Los Alamos National Laboratory[e]						
Normal	1.2×10^{0}	3.2×10^{-1}	2.6×10^{0}	7.5×10^{-1}	2.6×10^{0}	7.5×10^{-1}
Accident		5.4×10^{-2}		1.2×10^{-1}		1.2×10^{-1}
Oak Ridge National Laboratory						
Normal	6.0×10^{-1}	9.2×10^{-1}	1.4×10^{0}	2.0×10^{0}	1.1×10^{-2}	1.0×10^{0}
Accident		2.0×10^{-2}		4.5×10^{-2}		2.2×10^{-2}
Nevada Test Site[e]						
Normal	8.0×10^{-2}	3.2×10^{-2}	1.8×10^{-1}	7.0×10^{-2}	1.8×10^{-1}	7.0×10^{-2}
Accident		1.4×10^{-5}		3.2×10^{-5}		3.2×10^{-5}
Argonne National Laboratory - East						
Normal	3.6×10^{-2}	4.0×10^{-2}	8.0×10^{-2}	9.0×10^{-2}	5.5×10^{-4}	6.0×10^{-2}
Accident		1.4×10^{-4}		3.1×10^{-4}		1.1×10^{-4}
Lawrence Livermore National Laboratory						
Normal	3.2×10^{-1}	1.7×10^{-1}	7.5×10^{-1}	3.9×10^{-1}	2.6×10^{-3}	3.5×10^{-1}
Accident		3.6×10^{-3}		8.0×10^{-3}		6.5×10^{-3}

TABLE 5.10 Concluded

Facility	5-Yr Test Phase[b]		20-Yr Disposal Phase			
	100% Truck		100% Truck		Maximum Rail	
	Occupational[c]	Public[d]	Occupational	Public	Occupational	Public
Mound Laboratory						
Normal	5.6×10^{-2}	2.8×10^{-2}	1.3×10^{-1}	6.0×10^{-2}	3.7×10^{-4}	4.5×10^{-2}
Accident		8.4×10^{-5}		1.9×10^{-4}		1.8×10^{-6}
Cumulative Risk						
Normal	2.2×10^{1}	9.6×10^{0}	5.0×10^{1}	2.2×10^{1}	3.0×10^{0}	1.8×10^{1}
Accident	---	2.4×10^{0}	---	5.5×10^{0}	---	2.7×10^{0}
TOTAL	2.2×10^{1}	1.2×10^{1}	5.0×10^{1}	2.8×10^{1}	3.0×10^{0}	2.1×10^{1}

[a] Annual exposures are calculated from the lifetime exposures presented in Appendix D by dividing by five years for the Test Phase and 20 years for the Disposal Phase (Proposed and Alternative Action).

[b] Assumes 10% of shipments from all generator sites completed during Test Phase; all shipments are made by truck.

[c] Occupational population is all the transportation crews.

[d] Nonoccupational population.

[e] Waste shipments limited to truck mode. Rail risks are the same as truck risks.

TABLE 5.11 Annual radiological exposures (person-rem) for RH TRU Proposed Action waste shipments to the WIPP[a,b]

	20-Yr Disposal Phase			
	100% Truck		Maximum Rail	
Facility	Occupational[c]	Public[d]	Occupational	Public
Idaho National Engineering Laboratory				
Normal	2.4×10^{0}	2.0×10^{0}	1.6×10^{-2}	1.6×10^{0}
Accident		3.9×10^{-2}		1.6×10^{-2}
Hanford Reservation				
Normal	2.1×10^{1}	4.1×10^{1}	2.2×10^{-1}	1.8×10^{1}
Accident		5.5×10^{-3}		2.7×10^{-3}
Los Alamos National Laboratory				
Normal	1.4×10^{-1}	6.0×10^{-2}	1.4×10^{-1}	6.0×10^{-2}
Accident		1.6×10^{-5}		1.6×10^{-5}
Oak Ridge National Laboratory				
Normal	1.4×10^{1}	1.0×10^{1}	9.0×10^{-2}	8.5×10^{0}
Accident		1.1×10^{-3}		6.0×10^{-4}
Argonne National Laboratory - East				
Normal	7.5×10^{-1}	6.0×10^{-1}	4.1×10^{-3}	3.8×10^{-1}
Accident		9.5×10^{-5}		3.9×10^{-5}
Cumulative Risk				
Normal	3.8×10^{1}	5.4×10^{1}	4.7×10^{-1}	2.9×10^{1}
Accident	---	4.6×10^{-2}	---	1.9×10^{-2}
TOTAL	3.8×10^{1}	5.4×10^{1}	4.7×10^{-1}	2.9×10^{1}

[a] Annual exposures are calculated from the lifetime exposures presented in Appendix D by dividing by 20 years for the Disposal Phase.

[b] At the time of preparation of this SEIS, no RH waste was assumed during the Test Phase; therefore, postulated exposures for RH waste shipments are the same for either scenario.

[c] Occupational population is the total transportation crews.

[d] Nonoccupational population.

Doses to maximally exposed individuals in various population groups over the 25-year shipping campaign (Test Phase and Disposal Phase) for the Proposed Action are presented in Tables 5.12 and 5.13. Two sets of dose tabulations are provided: one for 100 percent truck shipments and one for maximum rail. The totals represent the dose expected for an individual whose residence or occupation results in an exposure to all or a large number (depending on exposure group) of waste shipments. For the Alternative Action, these maximum individual doses would be identical, except that they would be received over a 20-year period. The assumptions are discussed in detail in Appendix D.3.2.2.

Transportation Accidents. As discussed above, the FEIS evaluated transportation accident impacts by specifying individual accident scenarios and their associated probability of occurrence. AIRDOS-II was then used to estimate radiation doses to the public. Accident scenarios were developed for small urban areas such as Carlsbad, New Mexico, and large urban areas such as Albuquerque, New Mexico. Quantitative estimates of the occupational radiation risk, such as to the involved truck driver or train crew, resulting from transportation accidents were not made in the FEIS or in this SEIS. Personnel involved in waste transport will receive extensive training in emergency response and will follow predetermined safety procedures. Such training will minimize occupational exposures during accidents; however, actual exposures will be dependent on the exact nature of the accident and cannot be readily estimated.

This SEIS includes estimates of the impacts of TRU waste transportation accidents on the public using a modification of the RADTRAN computer code. RADTRAN estimates cumulative, probability-weighted dose consequences to the population along the routes from generator and storage facilities to the WIPP. As discussed in Appendix D.3, RADTRAN does not incorporate specific accident scenarios. Instead, potential accidents are divided into eight severity classes, each of which has an associated probability of occurrence and release fraction. Release fractions are different for accidents involving damage due to fire versus impact. It is assumed that two percent of potential accidents involving shipping containers result in fire (Appendix D.3). The probability of a given exposure to the population along the route is the product of accident frequency per mile, probability of occurrence of a given severity class accident, and the probability that the event will result in an impact or a fire. These probabilities are then summed over all severity classes.

The total population along the route is a sum of the products of the population density for rural, suburban, and urban zones, the length of the transportation route, and the fraction of travel through each of these zones. The population at risk due to external exposure rates for routine shipments is assumed to be that which resides within about 0.50 miles on either side of the transportation route. For accidents, the population at risk is modeled as the population in about a 1000 sq km area in the downwind dispersion pattern from the postulated accident. These and other input parameters for the RADTRAN model are summarized in Table D.3.7. The annual probability-weighted population doses for the accidents during the Proposed Action are also presented in Table 5.10 (for Alternative Action, see Table 5.47). Accident consequences were tabulated for 100 percent truck shipment and for maximum rail shipment of waste to the WIPP. Consequences of these radiation exposures are discussed below.

TABLE 5.12 Estimated maximum exposure to individuals within various population categories from incident-free transportation during the Test Phase and Disposal Phase for the Proposed Action and during the Disposal Phase for the Alternative Action (rem)*

100 % Truck Shipment Case

	Occupational					Nonoccupational		
	Crew Member[a]							
	In-Transit[b]	Stops[c]	Total[d]	Departure Inspections[e]	State Inspections[f]	On-Link[g]	Off-Link[h]	Stops[i]
Contact-Handled								
INEL	3.5×10^{1}	6.8×10^{0}	4.2×10^{1}	2.7×10^{-1}	8.1×10^{-1}	5.0×10^{-4}	1.5×10^{-4}	5.5×10^{-2}
RFP	5.4×10^{1}	1.0×10^{1}	6.4×10^{1}	7.6×10^{-1}	2.3×10^{0}	7.5×10^{-4}	4.2×10^{-4}	1.5×10^{-1}
Hanford	2.4×10^{1}	4.8×10^{0}	2.9×10^{1}	1.5×10^{-1}	4.3×10^{-1}	3.5×10^{-4}	8.1×10^{-5}	2.9×10^{-2}
SRS	1.1×10^{2}	1.9×10^{1}	1.3×10^{2}	4.8×10^{-1}	1.4×10^{0}	1.4×10^{-3}	2.6×10^{-4}	9.6×10^{-2}
LANL	2.9×10^{1}	7.6×10^{0}	3.7×10^{1}	5.7×10^{-1}	1.7×10^{0}	2.1×10^{-3}	3.1×10^{-4}	1.1×10^{-1}
ORNL	1.5×10^{1}	1.0×10^{1}	2.5×10^{1}	1.7×10^{-1}	5.0×10^{-1}	5.5×10^{-3}	9.1×10^{-5}	3.4×10^{-2}
NTS	1.8×10^{0}	3.6×10^{-1}	2.2×10^{0}	6.4×10^{-3}	1.9×10^{-2}	6.0×10^{-4}	3.5×10^{-6}	1.3×10^{-3}
ANLE	9.1×10^{-1}	4.1×10^{-1}	1.3×10^{0}	7.0×10^{-3}	2.1×10^{-2}	3.8×10^{-3}	3.8×10^{-6}	1.4×10^{-3}
LLNL	8.2×10^{0}	1.7×10^{0}	9.9×10^{0}	2.6×10^{-2}	7.8×10^{-2}	2.0×10^{-4}	1.5×10^{-5}	5.2×10^{-3}
MOUND	1.4×10^{0}	2.7×10^{-1}	1.7×10^{0}	4.1×10^{-3}	1.2×10^{-2}	2.1×10^{-4}	2.3×10^{-6}	8.3×10^{-4}
TOTAL (WIPP)[r]	–	–	–	2.4×10^{0}[q]	7.3×10^{0}	–	1.3×10^{-3}	4.8×10^{-1}
Remote-Handled								
INEL	2.4×10^{1}	1.1×10^{1}	3.5×10^{1}	2.0×10^{-1}	4.9×10^{-1}	2.5×10^{-3}	6.3×10^{-5}	4.1×10^{-2}
Hanford	8.4×10^{1}	9.2×10^{1}	1.8×10^{2}	3.3×10^{0}	7.9×10^{0}	8.0×10^{-3}	1.1×10^{-4}	6.6×10^{-1}
LANL	1.4×10^{0}	8.1×10^{-1}	2.2×10^{0}	7.5×10^{-2}	1.8×10^{-1}	4.5×10^{-3}	2.4×10^{-5}	1.5×10^{-2}
ORNL	4.5×10^{1}	1.7×10^{1}	6.2×10^{1}	1.2×10^{0}	3.0×10^{0}	1.6×10^{-3}	4.0×10^{-4}	2.5×10^{-1}
ANLE	7.7×10^{0}	2.9×10^{0}	1.1×10^{1}	6.3×10^{-2}	1.5×10^{-1}	1.3×10^{-3}	2.0×10^{-5}	1.3×10^{-2}
TOTAL (WIPP)[r]	–	–	–	4.8×10^{0}[q]	1.2×10^{1}	–	6.2×10^{-4}	9.8×10^{-1}
GRAND TOTAL	–	–	–	7.2×10^{0}	1.9×10^{1}	–	1.9×10^{-3}	1.5×10^{0}

TABLE 5.12 Continued

Maximum Rail Shipment Case

	Occupational						Nonoccupational	
	Crew Member[j]							
	In-Transit[b]	Stops[k]	Total[d]	Yard Crew[l]	Departure Inspections[m]	State Inspections[n]	Off-Link[h]	Stops[o]
Contact-Handled								
INEL	2.0×10^{-2}	1.3×10^{0}	1.3×10^{0}	5.4×10^{-2}	2.7×10^{-1}	6.1×10^{-1}	1.5×10^{-4}	2.8×10^{-2}
RFP	2.9×10^{-2}	1.9×10^{0}	1.9×10^{0}	1.5×10^{-1}	7.6×10^{-1}	1.7×10^{0}	4.2×10^{-4}	7.9×10^{-2}
Hanford	1.7×10^{-2}	1.1×10^{0}	1.1×10^{0}	2.9×10^{-2}	1.5×10^{-1}	3.2×10^{-1}	7.9×10^{-5}	1.5×10^{-2}
SRS	3.5×10^{-2}	2.3×10^{0}	2.3×10^{0}	9.5×10^{-2}	4.8×10^{-1}	1.1×10^{0}	2.6×10^{-4}	5.0×10^{-2}
LANL[p]	2.9×10^{1}	7.6×10^{0}	3.7×10^{1}	–	5.7×10^{-1}	1.7×10^{0}	3.1×10^{-4}	1.1×10^{-1}
ORNL	1.3×10^{-2}	1.5×10^{0}	1.5×10^{0}	3.4×10^{-2}	1.7×10^{-1}	3.8×10^{-1}	9.2×10^{-5}	1.7×10^{-2}
NTS[p]	1.8×10^{0}	3.6×10^{-1}	2.2×10^{0}	–	6.4×10^{-3}	1.9×10^{-2}	3.5×10^{-6}	1.3×10^{-3}
ANLE	1.4×10^{-3}	8.6×10^{-2}	8.7×10^{-2}	1.4×10^{-3}	7.0×10^{-3}	1.6×10^{-2}	3.9×10^{-6}	7.3×10^{-4}
LLNL	6.9×10^{-3}	4.5×10^{-1}	4.6×10^{-1}	5.2×10^{-3}	2.6×10^{-2}	5.9×10^{-2}	1.4×10^{-5}	2.7×10^{-3}
MOUND	7.9×10^{-4}	5.2×10^{-2}	5.3×10^{-2}	8.2×10^{-4}	4.1×10^{-3}	9.0×10^{-3}	2.3×10^{-6}	4.3×10^{-4}
TOTAL (WIPP)[r]	–	–	–	3.7×10^{-1}	2.4×10^{0q}	5.9×10^{0}	1.3×10^{-3}	3.0×10^{-1}
Remote-Handled								
INEL	2.6×10^{-2}	2.0×10^{0}	2.0×10^{0}	4.1×10^{-2}	2.0×10^{-1}	3.7×10^{-1}	6.6×10^{-5}	1.7×10^{-2}
Hanford	1.1×10^{-1}	2.0×10^{1}	2.0×10^{1}	6.6×10^{-1}	3.3×10^{0}	5.9×10^{0}	1.1×10^{-3}	2.8×10^{-1}
LANL[p]	1.4×10^{0}	8.1×10^{-1}	2.2×10^{0}	–	7.5×10^{-2}	1.8×10^{-1}	2.4×10^{-5}	1.5×10^{-2}
ORNL	3.2×10^{-2}	2.5×10^{0}	2.5×10^{0}	2.5×10^{-1}	1.2×10^{0}	2.3×10^{0}	3.9×10^{-4}	1.0×10^{-1}
ANLE	8.0×10^{-3}	6.1×10^{-1}	6.2×10^{-1}	1.3×10^{-2}	6.3×10^{-2}	1.1×10^{-1}	2.1×10^{-5}	5.2×10^{-3}
TOTAL (WIPP)[r]	–	–	–	9.6×10^{-1}	4.8×10^{0q}	8.9×10^{0}	1.6×10^{-3}	4.2×10^{-1}
GRAND TOTAL	–	–	–	1.3×10^{0}	7.2×10^{0}	1.5×10^{1}	2.9×10^{-3}	7.2×10^{-1}

TABLE 5.12 Continued

Notes:

* The Proposed Action transports the waste over a 25-year period, while the Alternative Action transports over a 20-year period.

[a] The fraction of shipments a crew member is estimated to participate in is calculated based on an availability of 5,400 hours per year (225 days at 24 hours per day) and an average travel speed of 35 mph for truck and 20 mph for rail.

[b] Based on RADTRAN-II model, with an exposure distance of 13 ft for truck shipments and 492 ft for rail shipments.

[c] Based on line source exposure model (l/r) for 100 mile inspections, food stops and refueling stops:

	Exposure Time	Exposure Distance	Comments
Inspections	15 min	3.2 ft	
Food stops			
Dining	1 hr	66 ft	
Surveillance	1 hr	33 ft	
Refueling			
Near activities	20 min	16 ft	Refueling assumed to
Far activities	20 min	33 ft	occur every 850 miles

[d] Total crew member occupational dose will be controlled by a dosimetry program.

[e] Calculated using a line source exposure model, with an average exposure distance of 10 ft and an exposure time of 30 minutes, and assuming three shifts per day and that the individual works in same position for 10 years.

[f] Based on line source exposure model with one inspector exposed to 20 percent of all shipments for 1 hour per inspection at an average distance of 3.2 ft (1 m).

[g] Assumes member of public is delayed in traffic adjacent to shipment for one 30-minute period, at a distance of 3.2 ft (1 m). This calculation gives the upper bound for the actual radiation dose due to the usage of conservative assumptions, as discussed in Subsection D.3.2.1 and Appendix B. There are no totals for this column since one person would not be delayed in traffic beside all shipments.

[h] Calculated using RADTRAN-II model which assumes that individual is exposed to every waste shipment traveling at 15 mph at a distance of approximately 100 ft.

[i] Estimated exposure using a line source exposure model to a member of the public working at a truckstop (exposure distance of 65 ft and exposure duration of 2 hours) and assuming all trucks stop at that location, three shifts per day, and that individual works at location for 10 years.

[j] Maximum rail crew member exposure calculation based upon the maximum anticipated distance between railcar classification terminals from each shipment site to the WIPP. The distances used in this analysis are: INEL/1,200 mi, RFP/770 MI, HANF/1,910 mi, SRS/875 mi, ORNL/850 mi, ANLE/1,180 mi, LLNL/1,680 mi, Mound/1,220 mi.

TABLE 5.12 Concluded

Notes (Concluded):

[k] Individual crew member doses during stops for inspections and servicing (e.g., air hose connections) were calculated, assuming an exposure duration of 1 percent of the stop time at an exposure level equaling the TI value.

[l] Calculated using line source model (1/r), with an average exposure distance of 33 ft (10 m) and an exposure duration of 2 hours for each shipment and assuming that there are three rotating yard crews, with an individual working 10 years in the same job.

[m] Assumed to be the same as for truck shipments since fewer rail shipments will be required but more items to inspect/survey per shipment.

[n] State inspector exposure parameters for rail are assumed to be the same as the truck mode, but with a reduced exposure time of 45 minutes, since no queue time is expected.

[o] Assumes individual is exposed to every waste shipment stopped at a train terminal, with an average exposure distance of 660 ft (200 m) for a duration of 20 hours. Dose rate calculated as a point source beyond 300 ft (approximately 5 times a railcar length) equaling 6.9×10^{-4} (TI).

[p] Waste shipments are limited to the truck mode.

[q] Arrival inspections.

[r] This is the total of the column and is equal to the total for a person working at or living near WIPP.

TABLE 5.13 Estimated annual average exposure (rem) for the hypothetical maximally exposed member of the general public (nonoccupational exposure)[a]

	100% Truck Shipment Case[b]		
	Proposed Action		Alternative Action
	Test Phase	Disposal Phase	Disposal Phase
Off-Link[c]	2.6×10^{-5}	9.0×10^{-5}	1.0×10^{-4}
Stops[d,e]	1.5×10^{-1}	1.5×10^{-1}	1.5×10^{-1}

	Maximum Rail Shipment Case[f]	
	Proposed Action	Alternative Action
Off-Link[c]	1.2×10^{-4}	1.4×10^{-4}
Stops[d,e]	7.2×10^{-2}	7.2×10^{-2}

[a] The Proposed Action transports the waste over a 25-year period, while the Alternative Action transports over a 20-year period. These values were derived from Table 5.12.

[b] The annual average in the 100% truck case for the Proposed Action was calculated by assuming 10 percent of the CH TRU waste is transported over a period of 5 years for the Test Phase and 90 percent of the CH plus 100 percent of the RH TRU waste is transported over a 20-year period for the Disposal Phase.

[c] Calculated using RADTRAN-II model which assumes that individual is exposed to every waste shipment traveling at 15 mph at a distance of approximately 100 ft.

[d] Estimated exposure using a line source exposure model to a member of the public working at a truckstop (exposure distance of 65 ft and exposure duration of 2 hours) and assuming all trucks stop at that location, three shifts per day, and that individual works at location for 10 years.

[e] The total dose for "stops" assumes the person works for 10 years at the same job. Therefore, the annual average is one-tenth of the grand total value in Table 5.12.

[f] The annual average in the maximum rail case for the Proposed Action was calculated by assuming 100 percent of the TRU waste is transported over a 25-year period.

As discussed in Subsection 5.2.2, "bounding case" transportation accident scenarios were developed for this SEIS. Those scenarios were used to calculate the impact of very severe accidents in higher population areas along the WIPP-preferred transportation routes. Postulated accidents involved both CH and RH truck and rail shipments using TRUPACT-II containers or RH casks. Waste compositions from Los Alamos National Laboratory, Savannah River Site and the Idaho National Engineering Laboratory were analyzed for CH TRU shipments, and from Hanford Reservation and the Idaho National Engineering Laboratory for RH TRU shipments. These waste compositions were scaled up to the maximum total curie content of radionuclides allowed by either the WIPP Waste Acceptance Criteria or the TRUPACT Payload Compliance Plan.

During each accident, all TRUPACT-II containers or casks were assumed to be equally breached and subsequently engulfed in fire for two hours (it is estimated that at least 17,000 gallons of fuel would be required to provide sufficient fuel to sustain a two-hour fire). External air/oxygen sources were assumed to be limited (internal combustion is limited) because a major breach of the Type B TRUPACT-II containers or RH casks is not credible. Radioactive contamination and hazardous chemicals were assumed to be evenly distributed throughout the waste volume and 0.02 percent of the lead in sludges and 0.02 percent of the radioactive particulate materials were postulated to be released in a respirable form (less than 10 micron particle size). The source term for hazardous chemicals also includes the release of volatile organic compounds and vaporized lead. Each accident was assumed to occur during a period having very stable atmospheric meteorological conditions, so as to limit dispersion or breakup of the plume and maximize radiation doses and hazardous chemical concentrations.

The RADTRAN and AIRDOS computer models (Appendix D.3) were used to evaluate the radiological consequences of each accident scenario. The AIRDOS model was used as a verification of the RADTRAN estimated consequences. A comparison of RADTRAN and AIRDOS parameters is shown in Tables D.3.29 and D.3.30.

Human Health and Environmental Consequences of Radiological Releases. Estimated releases of and consequent exposures to radioactive materials in the TRU waste poses potential risks to human health and the environment. The FEIS calculated radiological exposures for human populations and discussed the potential health effects associated with those exposures. In this SEIS assessment, risks to human health are expressed as an increase in the risk of fatal cancers due to radiological exposures.

Radiation can affect human health by causing cancer, genetic disorders, and other health problems. The Committee on Biological Effects of Ionizing Radiation (BEIR) of the National Academy of Sciences has published a detailed review of available data on radiation-induced health effects (BEIR, 1980). This report (BEIR III) uses a variety of data and accepted methods to quantify the health impacts of low levels of radiation. Its estimates of health risk associated with radiation exposure have been used to estimate the possible radiation-induced health effects that might be caused by operation of the WIPP; these potential health effects are discussed below.

The International Commission on Radiological Protection (ICRP) provides risk estimates for radiation exposure in Publication 26. BEIR III risk estimates were used in this SEIS

2because 1) BEIR III is a more comprehensive evaluation of radiation-induced health effects, and 2) BEIR III results in higher estimates of total health effects.

In 1988, the BEIR Committee issued a new report (BEIR-IV) which deals with the health risks of internally deposited alpha-emitters (BEIR, 1988). The risk figures in this report were used to reassess the health consequences of the dose equivalents predicted for the WIPP's operation and for foreseeable accidents. The results of this reassessment, contained in Appendix N, indicate that the risk estimates contained in the SEIS are appropriately conservative.

The BEIR III report identifies the following three categories of radiation-induced human health effects: 1) cancer, 2) genetic disorders, and 3) somatic effects other than cancer. The BEIR Committee believes that carcinomas are the most important effect of low-dose radiation. In this context, the term "low dose" refers to dose equivalents as high as a few rem per person per year. Natural background radiation ranges from 0.1 to 0.2 rem per person per year. Genetic effects of low-level radiation have been well documented and are addressed in detail in the BEIR III report. Somatic effects other than cancer include cataract induction and fertility impairment. The BEIR III report concludes that low-dose exposure of human populations does not increase the risk of somatic effects other than cancer and developmental changes in unborn children. The report also indicates that developmental changes in unborn children are probably not caused by radiation at or below natural background levels.

Cancer data from the Japanese survivors of nuclear detonations in World War II are used in most of the analyses in the BEIR III report. A major question addressed by the BEIR III report is how to extrapolate the cancer risks observed at the relatively high dose rates down to the lower dose rates typical of nuclear facilities. The BEIR III report adopted a parametric family of functions to accomplish this extrapolation. The linear model represents an upper limit or maximum risk; the linear-quadratic model, an intermediate or probable risk; and the quadratic model, a low limit or minimum risk. These functions have been suggested by the report for low-linear-energy-transfer (low-LET) radiation. This type of radiation includes gamma-, x-, and electron (beta particle) radiation. High-LET radiation includes alpha particles encountered in the decay of transuranic radionuclides. The risk estimate for high-LET radiation is encompassed by the estimates calculated for low-LET radiation, because the convention of effective dose equivalents was used to calculate radiation exposure.

One characteristic of radiation-induced cancer is that it takes a long time to develop, a period referred to as the "latency period." Leukemia has a characteristically short latency period (less than 25 years), whereas other cancers can have latency periods as long as the life span of the individual. Because only about 40 years of cancer data have been collected on the survivors of nuclear detonations, the data do not account for all the cancers that might develop because of the resultant radiation. The following two projection models have been developed to account for these future cancer deaths: 1) the absolute-risk projection model, which assumes that the cancer rate (risk per year) observed since the nuclear detonations will continue throughout the life spans of those exposed; and 2) the relative-risk model, which assumes that the excess radiation-induced risk is proportional to the natural incidence of cancer with age. The relative-risk model results in cancer risk estimates greater than those predicted by the absolute

model. However, the BEIR III report states that the absolute model is generally more applicable to most forms of cancer.

A health effects estimator for low-LET and high-LET radiation was selected from the range of values presented in the BEIR III report. It totals 280 cancer fatalities per million person-rem for low-LET and high-LET radiation.

Genetic effects consider the impact of radiation exposure received by the current population on future generations. Because they occur in the future, genetic effects are expressed in terms of the impact to offspring rather than to the current population. Using data from the BEIR-III report, the risk of genetic effects has been determined to be 257 effects per million live-born offspring for each rem of additional exposure received by the gonads of the affected population. This value is somewhat lower than the risk for latent cancer fatalities. Therefore, the risks of cancer provide a conservative estimate of the risks of genetic effects to future generations.

Using data which appeared in more recent publications, Appendix N reconsiders the question of genetic effects. The conclusion reached is that the estimator used in the SEIS is conservative for internally-deposited alpha emitters. It also confirms the validity of this genetic risk estimator for low-LET radiation.

These estimators could vary widely, depending on the models used. For cancer fatalities, estimators could range from near 0 to as high as 400 per million person-rem. For genetic effects, the risk estimators could range from 60 to 1,100 per million person-rem (Passmore, 1986).

Whether the absolute-risk model or the relative-risk model is used to project radiation-induced risks, the very low radiation exposures predicted in the SEIS lead to an insignificant number of health effects and risk values to the population. The use of ranges for risk estimates is not believed to be warranted in this SEIS because of the low levels of predicted risk.

The risk estimates presented in this subsection provide insight into the radiological impact that the WIPP could potentially have on the public. In response to such estimates, the government has established goals that broadly define an acceptable level of radiological and nonradiological risk (BEIR, 1980; EPA, 1986; NRC, 1986). At the present, the DOE has similar goals and guidance in draft DOE Order 5400.3 and DOE Order 6430.1A (DOE, 1988d, 1988e). These acceptable risk levels provide that nuclear risks should not significantly add to other societal risks. A range of quantitative risk values (from an increase in risk of 1 in 100,000 to 1,000,000) have been adopted by the above organizations and represent a risk of a health effect that should not exceed a one-tenth of one percent (0.1 percent) to a 1 percent increase in the number of similar health effects resulting from all other causes.

Radiological exposure can affect terrestrial and aquatic ecosystems. The major concern ecologically is protecting the vitality and integrity of plant and animal populations. Standards for humans, however, limit an individual's risk of any serious health effect (cancer), and the total health and genetic effects on human populations. In general, ecosystem species, particularly plants, can tolerate higher exposures than

those that have been determined acceptable for humans. It is highly likely that radiation levels that conform to limits designed to protect human individuals and populations will not have significant ecological effects.

Risks of Transportation-Related Radiation Exposures. Radiological risks from routine transportation are related to direct external gamma radiation. Releases are not expected during routine transportation because of the TRUPACT-II and RH cask design and performance criteria. Consequently, only the risks resulting from exposure to external radiation penetrating the shipping container or cask are considered for the routine transportation case. Predicted health impacts associated with routine transportation are presented in Table 5.14 (for Alternative Action, see Table 5.50). For the Proposed Action, estimated annual exposures associated with normal operations result in 2.5×10^{-2} and 9.7×10^{-4} excess latent cancer fatalities (LCFs) in the transportation work force per year during the Disposal Phase from truck and rail transportation, respectively, and 6.2×10^{-3} LCFs per year for truck transport during the Test Phase. Radiation exposures to the public from combined normal operations and accidents provide estimates of 2.3×10^{-2} and 1.4×10^{-2} excess LCFs per year in the total population along WIPP transportation corridors for the 100 percent truck and the maximum rail transport cases, respectively, for the Disposal Phase of the Proposed Action, and 3.4×10^{-3} LCFs per year for the Test Phase of the Proposed Action. The cumulative risk to the entire population along the transportation corridors associated with transportation accidents is very small. Also, the annual risk of developing a fatal cancer by the hypothetical maximally exposed individual exposed to shipments to the WIPP during the Disposal Phase of the Proposed Action is 0.025 (Off-Link) and 42 (Stops) chances per million for the 100 percent truck scenario, and 0.034 (Off-Link) and 20 (Stops) per million for the maximum rail scenario. ("Off-link" refers to an individual residing near the transportation route and "stops" refers to an individual working at a truck/rail stop). The assumptions utilized in estimating the risk for the hypothetical maximally exposed individual are very conservative. The radiological exposure to the ecosystems along the route would also be extremely small, and the associated impacts resulting from that exposure would be undetectable. To put the concept of "lifetime excess cancer risk" in perspective, the "background level" of cancer occurrence in the general population is about 1 in 4, or 225,000 cases in a population of 1,000,000 (American Cancer Society, 1988).

Appendix D, Subsection D.3.4.1 and Tables D.3.29 and D.3.30 present a discussion of the assumptions that were developed to estimate the exposures from a "bounding case" accident. The assumptions were used to calculate the impact of very severe accidents in higher population areas along the transportation routes. The assumptions were put into the RADTRAN computer code to determine radiological consequences. As a check on the estimated consequences, each bounding case scenario was also analyzed with the AIRDOS model.

The RADTRAN and AIRDOS codes were used to predict the consequences of the bounding case accident scenarios. The results showed that health effects may result from external exposure and internal exposure. Since it was assumed that the accidents occurred in an urban or suburban area, ingestion impacts associated with contamination of agricultural products were not applicable. No early fatalities or early morbidities would result from these exposures.

TABLE 5.14 Human health risks associated with radiological exposures during Proposed Action transportation to the WIPP

	Annual Health Risk[a,b,c] (latent cancer fatalities/year of operation)			
	Occupational		Public	
Transportation Activity	Test Phase	Disposal Phase	Test Phase	Disposal Phase
100% TRUCK				
Normal	6.2×10^{-3}	2.5×10^{-2}	2.7×10^{-3}	2.1×10^{-2}
Accident	- - -	- - -	6.7×10^{-4}	1.6×10^{-3}
TOTAL	6.2×10^{-3}	2.5×10^{-2}	3.4×10^{-3}	2.3×10^{-2}
Hypothetical maximally exposed individual[d] - Off-Link	- - -	- - -	7.3×10^{-9}	2.5×10^{-8}
- Stops	- - -	- - -	4.2×10^{-5}	4.2×10^{-5}
MAXIMUM RAIL				
Normal	- - -	9.7×10^{-4}	- - -	1.3×10^{-2}
Accident	- - -	- - -	- - -	7.6×10^{-4}
TOTAL	- - -	9.7×10^{-4}	- - -	1.4×10^{-2}
Hypothetical maximally exposed individual[d] - Off-Link	- - -	- - -	- - -	3.4×10^{-8}
- Stops	- - -	- - -	- - -	2.0×10^{-5}

[a] Transportation health risks are expressed as the annual number of excess fatal cancers estimated in the entire population along the shipping routes. (Both CH and RH TRU waste shipments are included.) Risks are expressed in exponential form; i.e., 1.0×10^{-3} is equivalent to 1.0 chance of a cancer in 1,000 for each year of operation.

[b] Risk of contracting fatal cancer: 2.8×10^{-4} fatalities/person-rem.

[c] Annual health effects risk estimates for genetic effects would be somewhat less than the risks presented in the table for cancer fatality risks as discussed in Appendix N.

[d] Risk expressed as chance of an individual member of the public contracting a fatal cancer due to the transportation of wastes to the WIPP. The assumptions are discussed in Appendix D, Subsection D.3.2.2.

For CH truck shipments, assuming a realistic 60-day resuspension half-life, the RADTRAN model projected a population dose of 1.52×10^4 person-rem for Los Alamos National Laboratory shipments through a suburban area, 4.95×10^4 person-rem for Savannah River Site shipments through an urban area, and 5.58×10^4 person-rem for the Idaho National Engineering Laboratory shipments through an urban area. These correspond to an estimated 4.3 LCFs for Los Alamos, 14 LCFs for Savannah River Site, and 16 LCFs for the Idaho National Engineering Laboratory, assuming the risk coefficient is 2.8×10^{-4} LCFs/person-rem. The AIRDOS model projected 6.55×10^3 person-rem (1.8 LCFs), for Los Alamos, 3.51×10^4 person-rem (9.8 LCFs), for the Savannah River Site and 3.97×10^4 person-rem for (11 LCFs) the Idaho National Engineering Laboratory. The AIRDOS model also projected a maximum individual dose of 0.16 rem, 0.16 rem, and 0.18 rem for Los Alamos National Laboratory, Savannah River Site, and the Idaho National Engineering Laboratory, respectively.

For CH rail shipments, the RADTRAN model projected 9.90×10^4 person-rem (28 LCFs) and 1.12×10^5 person-rem (31 LCFs) for Savannah River Site and the Idaho National Engineering Laboratory. Los Alamos National Laboratories does not have rail access. The AIRDOS model projected for the Savannah River Site 7.02×10^4 person-rem (20 LCFs) and 7.94×10^4 person-rem (22 LCFs) for the Idaho National Engineering Laboratory. The maximum individual doses are 0.32 and 0.36 rem for Savannah River Site and the Idaho National Engineering Laboratory, respectively. The results for rail shipments are double the results for truck shipments since rail shipments have twice as many TRUPACT-IIs or RH casks as truck shipments.

For RH truck shipments, the RADTRAN model projected 1.16×10^3 person-rem (0.32 LCFs) and 1.24×10^4 person-rem (3.5 LCFs) for Hanford and the Idaho National Engineering Laboratory, respectively. The AIRDOS model projects 8.99×10^2 person-rem (0.25 LCFs) and 9.00×10^3 person-rem (2.5 LCFs) for Hanford and the Idaho National Engineering Laboratory, respectively. The maximum individual doses are 0.004 rem and 0.04, respectively. For RH rail shipments, the results are double those for RH truck shipments.

As stated earlier, accidents of all severity categories, including category 8, are already included in the risk estimates provided in this subsection. The "bounding case" accident has an extremely low likelihood of occurring. The probability of breaching all Type B containers or casks during truck or rail accidents and engulfing them in a two-hour fire (requiring the fuel equivalent of two fully loaded fuel transports) in an urban or suburban area during adverse meteorological conditions is extremely small. The actual risk posed by this accident therefore is small since risk is dependent on the probability and the consequences of the event. Additional conservatism in the analysis included use of average population densities higher than currently exist along most transportation corridors, including Atlanta, Georgia; Denver, Colorado; and Albuquerque, New Mexico.

Impact of Supercompaction. Waste treatments such as supercompaction would reduce the total number of shipments to the WIPP. While a more dense waste form would be shipped, this SEIS analysis is still bounding for both normal and accident conditions. For example, the bounding case accidents in this SEIS are based on maximum amounts of radioactivity which can be carried by the TRUPACT; supercompacted waste would

remain within these limits. For accidents in general, the increase in exposure per shipment (due to more waste per shipment) would be offset by a reduction in the total number of shipments so that the overall population exposure for the entire campaign would be equal. The same analysis applies to incident-free exposures (exposure to people living along the route, people at stops, inspectors and other occupational categories of people who see multiple waste shipments); any increase in per shipment exposure would be offset by a corresponding decrease in the number of shipments. The total mass of radionuclides being transported remains the same, whether waste is supercompacted or uncompacted, so that the total population exposure resulting from transportation of these radionuclides remains the same. As an example, assume that 70 drums of unsupercompacted waste are to be shipped from Rocky Flats Plant and that this corresponds to 5 TRUPACT loads with a TRUPACT Transport Index of 1.5 as given in Table D.3.5. The contribution of any drum in a TRUPACT to the Transport Index is 1.5/14 = 0.107 millirem per hour per drum. Therefore, the campaign exposure rate for moving these 70 drums is 0.107 x 70 = 7 millirem per hour. If the waste in these drums were supercompacted with a 5:1 compaction ratio, each supercompacted drum would contribute 0.107 x 5 = 0.5 millirem per hour per drum. The 70 drums would then fit into 1 TRUPACT (70/5 = 14). The campaign exposure rate for this 1 TRUPACT would be 0.5 millirem per hour per drum x 14 drums, or 7 millirem per hour, the same as for unsupercompacted drums.

A scenario involving an individual exposed to a single shipment would be the only situation in which supercompacted waste could result in a higher radiation dose to a member of the public than unsupercompacted waste. An example would be when a person is stopped in traffic beside a shipment. The Transport Index for a shipment of supercompacted waste and the resulting dose to an exposed individual could change as a result of supercompaction of the waste.

A value for the upper bound of the radiation dose to a person stopped in traffic for 30 minutes beside a TRUPACT carrying Rocky Flats Plant waste that had not been supercompacted was calculated to be 0.75 mrem (see Table D.3.14). If the shipment contained supercompacted waste (with a 5:1 compaction ratio) and if the Transport Index increased in proportion to the compaction ratio, then the calculated upper bound for the radiation dose to an individual stopped next to this shipment would be 5 x 0.75 or about 3.8 mrem. However, because of the conservative assumptions in generating the 0.75 mrem estimate given in Table D.3.14, and additional conservatism relating specifically to supercompaction, the actual radiation dose would be much less than 3.8 mrem.

The conservative assumptions included: using a distance of 1 meter instead of the more likely 2 to 4 meters between the TRUPACT-II and the hypothetical maximally exposed individual; using a photon energy of 1 MeV instead of the actual 0.06 to 0.1 MeV to estimate the shielding effect of the TRUPACT-II; using the maximum surface dose rate on a drum to determine the Transport Index (if this were due to a localized area of contamination, supercompacting the drum would not increase the Transport Index); and ignoring the increase in self-shielding within the waste due to the increase of the density in the waste by supercompaction.

5.2.2.2 Hazardous Chemical Risk Assessment for Transportation. This subsection evaluates risks associated with exposures to hazardous chemicals during the transport of TRU waste to the WIPP. Maximum potential hazardous chemical exposures to a

person during accidents are discussed. Accidents involving hazardous chemicals are evaluated as short-term events with respect to potential exposures and associated risks.

Routine Exposures from Transportation Activities. As described in Subsection 5.2.2.1, during routine transportation, minimal gamma exposures exist at the surface of the TRUPACT-IIs. Exposures to hazardous chemicals during routine transport are unlikely because the hazardous chemical components of the waste are completely contained within the TRUPACT-II package. Thus, no exposures or risks to human health are posed by the hazardous chemical components under routine transportation conditions. This assessment examines the potential human health impacts resulting from transportation accident scenarios that are postulated for truck and rail shipments of TRU mixed waste to the WIPP.

Transportation Accidents. The "bounding case" accident scenario was based on the unlikely assumption that all TRUPACT-IIs and all 14 drums in every TRUPACT-II in a waste shipment are breached. Consistent with the radiological assessment (Subsection 5.2.2.1), the entire releasable fraction of each chemical considered was used to evaluate potential risks of exposure (this chemical fraction consists of vapors and suspended particulates). Whenever possible, assumptions used in the radiological assessment (Subsection 5.2.2.1) provide the basis for assessing the risks of accidents posed by the hazardous chemical components of the waste. Any differences in assumptions noted in this section are necessary to account for the actual forms in which the chemicals are available for release during an accident. For example, while the radioactive component of the waste may be released only as particulates, the organic chemicals available for release exist primarily as vapors; thus, specific assumptions that address the behavior of vapors have been developed. These assumptions are described in more detail below. Hazardous chemicals in TRU mixed waste occur in the forms of volatile organic compounds (VOCs) and metals.

Selection of Hazardous Chemicals for Assessment. The VOCs examined in this assessment are carbon tetrachloride; methylene chloride; 1,1,1,-trichloroethane; 1,1,2-trichloro-1,2,2-trifluoroethane (Freon-113); and trichloroethylene; the metal examined is lead. As waste, these chemicals are the EPA-regulated hazardous components that may potentially comprise greater than one percent by weight of the waste transported to the WIPP (Rockwell, 1988) and are considered hazardous by the EPA (40 CFR Part 261, Subparts C and D). All others are estimated to comprise less than one percent each by weight of the waste, and most exist only in trace quantities (WEC, 1989). Although trichloroethylene was not reported in newly generated waste from the Rocky Flats Plant, it was detected in the headspace gas of drums containing older waste at the Idaho National Engineering Laboratory (Clements and Kudera, 1985). Because data on the headspace gas concentration of trichloroethylene were available, it was included in this assessment. The volatile organic compounds listed above have not been identified in RH TRU waste; lead, however, is found in RH and CH TRU waste (WEC, 1989).

With regard to toxicity, carbon tetrachloride, trichloroethylene and methylene chloride are considered potential carcinogens by the EPA, and 1,1,1-trichloroethane and Freon-113 may produce adverse somatic effects. Lead is the most abundant metal found in the waste by both weight and volume (WEC, 1989). The risks of exposure to the relatively high concentrations of lead released during an accident are expected to be bounded by the risks of exposure to any of the other hazardous, RCRA-regulated metal

because they exist in much smaller quantities (WEC, 1989). In sufficient concentrations, exposure to lead has been found to cause damage to the central nervous system and loss of kidney function. Further discussion describing how hazardous chemical components were selected and evaluated is provided in Subsection 5.2.4. Detailed toxicity information for each constituent is provided in Appendix G.

Quantities of Hazardous Chemicals Released. The following assumptions provided the basis for determining the total fraction of volatile organic compounds available for release during a transportation accident:

- An average void volume of 147 liters per drum was assumed [based on data collected by Clements and Kudera (1985)].

- The concentrations of volatile organic compounds in the void volume of each drum were derived from headspace gas measurements reported by Clements and Kudera (1985). These measurements were based on analyses of TRU mixed waste stored in containers at the Idaho National Engineering Laboratory (Subsection 5.2.4.1). The following average headspace gas concentration (in grams per cubic meter) was calculated for each volatile organic compound evaluated in this assessment: carbon tetrachloride, 1.9; methylene chloride, 0.5; 1,1,1-trichloroethane, 13.2; Freon-113, 1.2; and trichloroethylene, 0.7.

- One hundred percent of the total quantity (in grams) of each volatile organic compound within the void volume of each drum was assumed to discharge within the TRUPACT-II cavity prior to release to the atmosphere during an accident.

The assumptions used to determine the fraction of lead that may be released during an accident are as follows:

- The total quantity of lead released was comprised of particulates resuspended in the atmosphere of the drum and additional lead that was released under conditions in which extremely high temperatures cause a portion of the lead to vaporize.

- Each drum contains 227 kg of waste. A maximum concentration of 10 mg/kg for lead in sludges reported by the Rocky Flats Plant (Rockwell, 1988) was used to determine the quantity of lead potentially present in particulate form. Lead particulates from sludges were assumed to behave similarly to plutonium particulates released during an accident involving a fire (Mishima, 1973).

- Of the total material contained within each TRUPACT-II, 0.02 percent may be resuspended and released to the environment as particulates (Appendix D); for this analysis, lead comprised this entire particulate fraction. All of these particulates were assumed to be less than 10 microns in diameter, all of which are respirable.

- In addition to the particulate lead, the surface area over which vaporization of lead occurs during a fire was calculated as the product of the number

of drums and the cross-sectional area of a drum. (For RH TRU transportation, the outside surface area of a canister was included in the total area.)

- Temperature inside the TRUPACT-II during the fire was assumed to be 1,000 degrees Fahrenheit (811 degrees Kelvin); the fire's duration was 2.0 hours. The temperature inside the TRUPACT-II was assumed to reach 1,000 degrees Fahrenheit within one half-hour and be maintained for 1.5 hours to calculate a release fraction for vaporized lead.

In considering releases of lead and volatile organic compounds, it was assumed that, for CH TRU waste, 3 TRUPACT-IIs each contained 14 drums of waste during truck shipments, and that there would be 6 TRUPACT-IIs on each railcar shipment. For RH TRU waste, each truck would carry one cask and each railcar would carry two casks.

Human Health Consequences of Chemical Releases During Transport. The concentration of hazardous chemicals received by a maximally exposed individual was determined using the PUFF model (Petersen, 1982). The potential receptor (i.e., exposed individual) was assumed to be an average individual weighing 70 kg (154 lbs) whose daily respiratory volume was 20 m^3/day (EPA, 1985). The exposed individual was located 50 meters (164 feet) away from the accident in the pathway of the contaminant plume.

The volatile organic compounds released as gases during an accident in which drums and TRUPACT-IIs were breached were assumed to be available for intake by an exposed individual. The total quantities of volatile organics released during truck and railcar accidents are shown in Table 5.15. The total grams of each volatile organic compound potentially available for release is calculated by multiplying the average headspace gas concentrations (Clements and Kudera, 1985) by the average void volume in 14 drums. The concentrations of volatile organic compounds at an exposed individual located 50 meters from both the postulated truck and railcar accidents are provided in Tables 5.16 and 5.17, respectively. A detailed description of the methodologies used to calculate the estimated intakes, threshold limit value (TLV)-based allowable intakes, and TLV-based hazard indices are provided in Appendix G. The hazard indices range from 6.9×10^{-6} for 1,1,2-trichloro-1,2,2-trifluoroethane to 5.3×10^{-3} for carbon tetrachloride. The results indicate that exposures to volatile organic compounds in a severe transportation accident involving a truck or railcar are below health-based reference levels.

To determine whether an accident involving a fire would release a greater concentration of volatile organics, the effects of temperature increases on generation of gases within a TRUPACT-II were examined. The volatile organics present in the waste include compounds that exert measurable vapor pressures at room temperatures (e.g., Freon-113 and methylene chloride). It should be noted that headspace gas concentrations cannot be directly correlated to the total concentrations in the waste because of the complex nature of the vapor-waste equilibria distribution of the organics. For example, in waste forms with bound water (i.e., solidified sludges), the vapor pressure of the organics is reduced appreciably. Based on the data reported by Clements and Kudera (1985), the concentrations of volatile organic compounds in the headspace of the drums are well below the saturation values for these compounds in their pure state. Clements and Kudera (1985) observed a decrease in the concentrations of volatile organics in the headspace of drums containing combustibles when they were

TABLE 5.15 Quantities of volatile organic compounds available for release during accident scenarios[a]

CHEMICAL	Truck shipment: Three TRUPACT-IIs (g)	Rail shipment: Six TRUPACT-IIs (g)
Carbon tetrachloride	11.4	22.8
Methylene chloride	2.9	5.8
1,1,1-trichloroethane	81.6	163.2
Trichloroethylene	4.3	8.6
1,1,2-trichloro-1,2,2-trifluoroethane	7.5	15.0

[a] Initial concentrations of volatile organic compounds are estimated from data obtained from Clements and Kudera (1985).

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TABLE 5.16 Estimated exposures to volatile organic compounds and associated risks from a transportation accident involving truck shipments

Chemical	Receptor concentration (mg/m^3)	Estimated intake[a] (mg/exposure)	TLV-TWA[b] (mg/m^3)	TLV-based allowable intake[c] (mg/exposure)	TLV-based hazard index[d]
Carbon tetrachloride	2.3×10^{0}	9.5×10^{-1}	30	3.6×10^{2}	2.7×10^{-3}
Methylene chloride	5.8×10^{-1}	2.4×10^{-1}	175	2.1×10^{3}	1.2×10^{-4}
1,1,1-trichloroethane	1.6×10^{1}	6.8×10^{0}	1900	2.3×10^{4}	3.0×10^{-4}
Trichloroethylene	8.7×10^{-1}	3.6×10^{-1}	270	3.2×10^{3}	1.1×10^{-4}
1,1,2-trichloro-1,2,2-trifluoroethane	1.5×10^{0}	6.3×10^{-1}	7600	9.1×10^{4}	6.9×10^{-6}

[a] Estimated intakes are based on formula: Intake=Receptor Conc. x Respiratory Volume x Exposure Period. Respiratory volume is assumed to be 20 m^3/day.

[b] ATSDR, 1988.

[c] The TLV is a time-weighted average for an 8-hour period. Therefore, the TLV-based allowable intake uses the formula in (a) above with an exposure period of 8 hours.

[d] TLV-based hazard index = Estimated Intake/TLV-Based Allowable Intake.

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TABLE 5.17 Estimated exposures to volatile organic compounds and associated risks from a transportation accident involving rail shipments

Chemical	Receptor concentration (mg/m^3)	Estimated intake[a] (mg/exposure)	TLV-TWA[b] (mg/m^3)	TLV-based allowable intake[c] (mg/exposure)	TLV-based hazard index[d]
Carbon tetrachloride	4.6×10^{0}	1.9×10^{0}	30	3.6×10^{2}	5.3×10^{-3}
Methylene chloride	1.2×10^{0}	4.8×10^{-1}	175	2.1×10^{3}	2.3×10^{-4}
1,1,1-trichloroethane	3.3×10^{1}	1.4×10^{1}	1900	2.3×10^{4}	6.0×10^{-4}
Trichloroethylene	1.7×10^{0}	7.3×10^{-1}	270	3.2×10^{3}	2.2×10^{-4}
1,1,2-trichloro-1,2,2-trifluoroethane	3.0×10^{0}	1.3×10^{0}	7600	9.1×10^{4}	1.4×10^{-5}

[a] Estimated intakes are based on formula: Intake=Receptor Conc. x Respiratory Volume x Exposure Period. Respiratory volume is assumed to be 20 m^3/day.

[b] ATSDR, 1988.

[c] The TLV is a time-weighted average for an 8-hour period. Therefore, the TLV-based allowable intake uses the formula in (a) above with an exposure period of 8 hours.

[d] TLV-based hazard index = Estimated Intake/TLV-Based Allowable Intake.

vented for 13 weeks and then purged, sealed, and re-equilibrated for 13 more weeks. These results indicate that the source term of the organics was limited. In addition, at the temperature postulated for the "bounding case" accident (i.e., 1300°K), it is highly likely that the volatile organics would be consumed in the fire and broken down into CO_2 and H_2O. Based on the available information, the contribution to risk associated with the releases of volatile organic compounds involved in a fire was considered limited.

With regard to lead, it is similarly assumed that the receptor (i.e., exposed individual) is exposed to the entire fraction released, which, during a fire scenario, is the sum of the vapor and particulate phases. Consistent with the radiological analyses, an average weight of 227 kg (500 lbs) per drum was used to calculate the particulate release fraction. Based on the 10 mg/kg of lead per drum, the total quantity of lead was 2.3 g (.08 oz) per drum. To estimate the human health risk associated with exposure to this lead, a hazard index was calculated as described in Appendix G. The rate of particulate lead deposition in the lungs may range from approximately 30 to 50 percent of the particles inhaled, while up to 70 percent of deposited lead may be absorbed during a 30-minute exposure period (ATSDR, 1988). The concentrations of lead received by an individual receiving the maximum exposure downwind from truck and rail car shipments of CH and RH TRU waste are given in Table 5.18. Estimates of intake per exposure were compared with TLV-based allowable intakes (ACGIH, 1986). The methodology used to calculate the TLV-based allowable intake is included in Appendix G. The hazard index for a given chemical is defined as the ratio between the estimated intake of that chemical and a reference level (EPA, 1986). A hazard index of less than one implies that the exposure to the chemical is below the reference level. The TLV-based hazard indices for truck and railcar shipments involving CH TRU waste were 1.0×10^{-3} and 2.1×10^{-3}, respectively. These values are approximately three orders of magnitude below unity. Releases of lead from RH TRU waste shipments involved in this accident scenario resulted in hazard indices approximately four orders of magnitude below unity. The intakes of lead over a 30-minute exposure period are well below the reference level for an accident involving shipments of either CH or RH TRU waste.

In an accident involving a severe fire, there is a potential for release of a wide range of combustion products from the burning of plastics and other combustibles. As discussed in Subsection 5.2.2.1, a major breach of the TRUPACT-II was not considered to be a realistic event, and therefore external oxygen/air sources would be limiting (i.e., when internal combustion is limited).

In conclusion, no adverse human health effects are expected to result from exposure to the hazardous chemical constituents of TRU waste released during a transportation accident in which all TRUPACT-IIs in a shipment are breached, and any human health risks associated with such releases are negligible. The two primary reasons for the lack of adverse impacts are the low initial concentrations of chemicals within the waste containers and the physical form of the waste, which limits the concentrations available for release.

TABLE 5.18 Exposures and risk associated with releases of lead during an upper-bound accident scenario

Mode of transport	Quantity of lead available for release (mg)	Maximum receptor concentration (mg/m^3)	Estimated intake[a] (mg/exposure)	TLV-based hazard index[b,c]
		CH TRU Waste		
Truck	22.3	4.5×10^{-3}	1.9×10^{-3}	1.0×10^{-3}
Rail	44.5	8.9×10^{-3}	3.7×10^{-3}	2.1×10^{-3}
		RH TRU Waste		
Truck	3.2	6.5×10^{-4}	2.7×10^{-4}	1.5×10^{-4}
Rail	6.5	1.3×10^{-3}	5.4×10^{-4}	3.0×10^{-4}

[a] Estimated intakes are calculated by multiplying four factors: the concentration received by the exposed person, in milligrams per cubic meter of air; the quantity of air inhaled, in cubic meters; the exposure period, 30 minutes per exposure; and the conversion factor for days to minutes, 1 day per 1440 minutes.

[b] The TLV is a time-weighted average for an 8-hour work day intended to protect workers over a career of exposure. Therefore, the TLV-based allowable intake was estimated using the formula in Appendix G with an exposure period of 8 hours. It is equal to 6.3×10^{-1} mg/exposure.

[c] The TLV-based hazard index is the estimated intake divided by the TLV-based allowable intake with a 30 minute estimated intake provides a large margin of conservatism. An 8-hour standard is more stringent than a comparable standard based on a 30-minute exposure.

5.2.2.3 Physical injuries/fatalities during accidents and risks related to vehicle emissions. This subsection discusses the risks of physical injuries and deaths during transportation accidents and the risks associated with vehicle emissions during incident-free transportation. None of these risks is related to radioactivity or hazardous chemicals and would be the same as the risk resulting in everyday life from transporting nonradioactive materials. The accident risks are calculated as numbers of injuries and deaths; the vehicle-emission risks are calculated as numbers of excess latent cancer fatalities in the exposed population.

These risks are calculated on a per-shipment basis and on a lifetime basis (by transport mode) by alternative. Estimates of the per-shipment risk include the probability of latent cancer fatalities from vehicle-emission pollutants and accident-related injuries and deaths of a single round trip. Cumulative risk estimates were determined by multiplying per-shipment risks by total shipments for the five-year Test Phase and for the 20-year Disposal Phase, depending on the alternative and the transportation mode.

The average distance and population zone fractions are provided in Appendix D, Table D.4.2. These data are used with Tables 5.19 and 5.20 to calculate the per-shipment risk for truck and rail modes. The estimates in Table 5.19 represent the estimated additional urban-area health effects from the particulates and sulfur dioxide emitted by truck or locomotive diesel engines during a shipment. Table 5.21 presents the estimated per-shipment risk for truck and rail transport. The estimated risk shown for each generating and storage facility is on a round-trip basis. Appendix D.4 presents detailed descriptions of the methods, models, assumptions, and results used to estimate risks.

Results. SEIS Appendix D (Tables D.4.6, D.4.7, D.4.8, D.4.9, D.4.10 and D.4.11) presents the total-risk estimates for truck and rail for the per shipment risk approach as described in Appendix D.4.2.

For the Proposed Action shipment of CH TRU waste, the total risks for the Test Phase are 0.011 latent cancer fatality (LCF), 0.48 fatality, and 6.3 injuries for truck shipment. For CH TRU waste transport by truck, the total estimated risk for all sites for the 20-year Disposal Phase are 0.099 LCF, 4.4 fatalities, and 57 injuries. For CH TRU waste transport by rail, the total estimated risks for the Test Phase and the Disposal Phase are 0.078 LCF, 1.9 fatalities, and 21 injuries.

For Proposed Action RH TRU waste truck shipments, the estimated risks for LCFs, fatalities, and injuries are 0.062, 2.3, and 29, respectively. The estimated risks for rail transportation are 0.031 LCF, 0.66 fatality, and 7.1 injuries.

Annual average risks can be estimated by dividing the Test Phase total risks by 5 years and the Disposal Phase risks, both for the Proposed Action and the Alternative Action, by 20 years.

The risks using the lifetime risk approach described in Appendix D, Subsection D.4.2.2, are summarized in Tables D.4.12, D.4.13, and D.4.14.

TABLE 5.19 Air pollutant unit consequence factors[a]

Source	Health Effects per Mile	
	Truck	Rail
	(LCF/Mi)	(LCF/Mi)
Pollutants (particulates & sulfur dioxide)	1.6×10^{-7} (urban travel only)	2.1×10^{-7} (urban travel only)

LCF = Latent Cancer Fatalities

Source:

[a] Rao et al., 1982.

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TABLE 5.20 Nonradiological and nonchemical unit risk factors[a]

Mode	Zone	LCF/Mi[a]	Injuries/Mi[b]	Fatalities/Mi[b]
Truck	Rural	0	1.33×10^{-6}	1.09×10^{-7}
	Suburban	0	6.32×10^{-7}	2.69×10^{-8}
	Urban	1.6×10^{-7}	6.16×10^{-7}	1.54×10^{-8}
Rail	Rural	0	4.78×10^{-7}	4.54×10^{-8}
	Suburban	0	4.78×10^{-7}	4.54×10^{-8}
	Urban	2.1×10^{-7}	4.78×10^{-7}	4.54×10^{-8}

LCF = Latent Cancer Fatalities

Sources:

[a] Rao et al., 1982.

[b] Cashwell et. al., 1986.

TABLE 5.21 Per shipment nonradiological risk of waste shipments

		Truck			Rail		
			Accident Case			Accident Case	
Facility	Zone	Normal transportation LCF[a,b]	Fatalities	Injuries	Normal transportation LCF	Fatalities	Injuries
INEL	Rural	0.00×10^{0}	2.82×10^{-4}	3.44×10^{-3}	0.00×10^{0}	1.43×10^{-4}	1.51×10^{-3}
	Suburban	0.00×10^{0}	1.13×10^{-5}	2.65×10^{-4}	0.00×10^{0}	1.57×10^{-5}	1.65×10^{-4}
	Urban	5.84×10^{-6}	5.62×10^{-7}	2.25×10^{-5}	5.18×10^{-6}	1.12×10^{-6}	1.18×10^{-5}
RFP	Rural	0.00×10^{0}	1.57×10^{-4}	1.91×10^{-3}	0.00×10^{0}	8.64×10^{-5}	9.10×10^{-4}
	Suburban	0.00×10^{0}	7.38×10^{-6}	1.73×10^{-4}	0.00×10^{0}	1.16×10^{-5}	1.22×10^{-4}
	Urban	5.59×10^{-6}	5.38×10^{-7}	2.15×10^{-5}	7.84×10^{-6}	1.69×10^{-6}	1.78×10^{-5}
HANF	Rural	0.00×10^{0}	3.57×10^{-4}	4.36×10^{-3}	0.00×10^{0}	1.83×10^{-4}	1.93×10^{-3}
	Suburban	0.00×10^{0}	1.38×10^{-5}	3.24×10^{-4}	0.00×10^{0}	2.40×10^{-5}	2.52×10^{-4}
	Urban	5.51×10^{-6}	5.30×10^{-7}	2.12×10^{-5}	6.75×10^{-6}	1.46×10^{-6}	1.54×10^{-5}
SRS	Rural	0.00×10^{0}	2.57×10^{-4}	3.13×10^{-3}	0.00×10^{0}	1.32×10^{-4}	1.39×10^{-3}
	Suburban	0.00×10^{0}	2.14×10^{-5}	5.03×10^{-4}	0.00×10^{0}	3.89×10^{-5}	4.10×10^{-4}
	Urban	3.04×10^{-6}	2.93×10^{-7}	1.17×10^{-5}	1.29×10^{-5}	2.78×10^{-6}	2.93×10^{-5}
LANL	Rural	0.00×10^{0}	6.74×10^{-5}	8.22×10^{-4}			
	Suburban	0.00×10^{0}	1.83×10^{-6}	4.29×10^{-5}	d	d	d
	Urban	c	0.00×10^{0}	0.00×10^{0}			
ORNL	Rural	0.00×10^{0}	2.31×10^{-4}	2.82×10^{-3}	0.00×10^{0}	1.18×10^{-4}	1.24×10^{-3}
	Suburban	0.00×10^{0}	1.50×10^{-5}	3.53×10^{-4}	0.00×10^{0}	2.80×10^{-5}	2.95×10^{-4}
	Urban	3.02×10^{-6}	2.91×10^{-7}	1.16×10^{-5}	8.90×10^{-6}	1.92×10^{-6}	2.03×10^{-5}
NTS	Rural	0.00×10^{0}	2.43×10^{-4}	2.97×10^{-3}			
	Suburban	0.00×10^{0}	7.75×10^{-6}	1.82×10^{-4}	d	d	d
	Urban	8.23×10^{-6}	7.92×10^{-7}	3.17×10^{-5}			
ANLE	Rural	0.00×10^{0}	2.36×10^{-4}	2.88×10^{-3}	0.00×10^{0}	1.09×10^{-4}	1.15×10^{-3}
	Suburban	0.00×10^{0}	1.63×10^{-5}	3.82×10^{-4}	0.00×10^{0}	2.27×10^{-5}	2.39×10^{-4}
	Urban	4.44×10^{-7}	4.27×10^{-8}	1.71×10^{-6}	8.64×10^{-6}	1.87×10^{-6}	1.97×10^{-5}
LLNL	Rural	0.00×10^{0}	2.74×10^{-4}	3.34×10^{-3}	0.00×10^{0}	1.45×10^{-4}	1.52×10^{-3}
	Suburban	0.00×10^{0}	7.92×10^{-6}	1.86×10^{-4}	0.00×10^{0}	2.43×10^{-5}	2.56×10^{-4}
	Urban	1.73×10^{-5}	1.66×10^{-6}	6.65×10^{-5}	6.29×10^{-6}	1.36×10^{-6}	1.43×10^{-5}
Mound	Rural	0.00×10^{0}	2.42×10^{-4}	2.95×10^{-3}	0.00×10^{0}	1.17×10^{-4}	1.23×10^{-3}
	Suburban	0.00×10^{0}	1.91×10^{-5}	4.48×10^{-4}	0.00×10^{0}	3.24×10^{-5}	3.41×10^{-4}
	Urban	2.36×10^{-6}	2.27×10^{-7}	9.07×10^{-6}	1.34×10^{-5}	2.89×10^{-6}	3.05×10^{-5}

[a] Numbers are expressed in scientific notation. $2.82 \times 10^{-4} = 0.000282$.

[b] Latent cancer fatalities resulting from incremental vehicle pollution in urban population zones.

[c] The preferred route from LANL to WIPP passes through no urban population zones.

[d] LANL and NTS have no rail access.

5.2.2.4 Comparison of Transuranic Waste Transport Accident, Injury, and Fatality Projections. In the draft SEIS, impacts were assessed for waste transport by truck (34,144 shipments) and by maximum rail (18,467 shipments) for the proposed 25-year combined Test Phase and Disposal Phase at the WIPP. In response to comments that the number of shipments was inflated artificially by the addition of a drum void volume factor, the final SEIS estimates a total number of truck shipments (28,866 shipments) and maximum rail shipments (15,558 shipments).

For the truck shipment of TRU waste, the total estimated consequences for the projected 25-year Test and Disposal Phases in the draft SEIS was 8.3 fatalities and 106 injuries for the Proposed Action, as opposed to this revised final SEIS of 7 fatalities and 92 injuries, respectively.

The total estimated consequence for rail transport for the Proposed Action in the draft SEIS was 3 fatalities and 34 injuries. For this final supplement, the numbers have been revised to a projection of approximately 3 fatalities and 25 injuries for the maximum rail mode.

It must be emphasized that the total number of injuries and fatalities projected for truck transport in the draft SEIS were calculated based on Cashwell data (1986). In those projections, the injury rate per truck vehicle-mile traveled ranged from 6.16×10^{-7} for urban areas to 1.33×10^{-6} for rural areas. This is in contrast to the values that were obtained from 23 States during the preparation of this final SEIS, which indicate an overall weighted average of 3.75×10^{-7}, which is significantly lower than the number that was projected in the draft.

Similar analysis of fatality rates found that the numbers used in preparation of the draft ranged from 1.54×10^{-8} for urban areas to 1.9×10^{-7} for rural areas, as opposed to an overall system weighted average of 1.98×10^{-8} (23 States data).

The number used in the draft SEIS of 1.70×10^{-6} accidents per vehicle truck mile was more conservative than State data which currently show an overall average of 1.37×10^{-6} accidents per vehicle truck mile.

Consideration of data that were obtained from the States would result in an overall significantly lower number of accidents, injuries, and fatalities than projected in this SEIS, and again supports the conclusion that SEIS projections are conservative.

5.2.3 Risk Assessment and Analysis of Radiological Environmental Consequences of Operations and Possible Retrieval of Waste at the WIPP

This subsection establishes the general approach used in the SEIS to analyze both radiological and nonradiological impacts and examines the potential radiological environmental consequences associated with emplacement and, if necessary, retrieval of wastes from the WIPP. This subsection discusses potential releases and release pathways and presents the resulting exposure to humans or levels of environmental contamination with the resulting radiological impacts to human health and safety, and to the environment. Both routine operations and potential accident scenarios are considered. Subsection 5.2.3.1 describes the general methodology used to assess the

potential risks posed by the radiological and the hazardous chemical waste constituents.

5.2.3.1 General Risk Assessment Methodology. Environmental consequences of possible releases of radionuclides and hazardous chemicals proposed for emplacement in the WIPP are analyzed through a process of risk assessment. Risk assessment is a method of determining the likelihood and extent of consequences to human health and the environment posed by certain activities or events. The focus of the risk assessment is the waste management process proposed for the WIPP, which includes unloading of TRUPACT-II containers at the waste handling building, placement of waste in the repository, and retrieval of the waste at the conclusion of the Test Phase, if determined necessary. Some identified risks are analyzed quantitatively while others are evaluated using qualitative methods.

Overall Approach. The risk assessment in this subsection of the SEIS considers radiological and hazardous chemical risks to workers (occupational risks), risks to the general public, and impacts to the environment (ecological risks to ecosystems) at or near the WIPP facility. SEIS Subsection 3.1.1 and Appendix B provide information on radiological and hazardous chemical characteristics of radioactive mixed waste, respectively. Exposures (doses) potentially received by human populations or components of the ecosystem are derived from projected routine and postulated accidental releases. Human health effects are generally assessed in terms of excess lifetime fatal cancer risk. Other environmental and ecological effects are estimated in terms of adverse consequences on air or water quality and the degradation of ecological resources.

The risk assessment process can be generally divided into five basic steps:

1) Identify hazards (risks) considering the radiological, toxicological, and physical characteristics of the waste.

2) Evaluate routine operations or postulate reasonably foreseeable accident scenarios that may result in a release of radioactive material or toxic chemicals.

3) Conduct an exposure assessment by evaluating migration pathways and estimating exposure concentrations to which human and nonhuman receptors are subjected. Exposures are assessed by use of computer models such as AIRDOS-EPA for radiological releases and the Industrial Source Complex (ISC) Code for chemical releases.

4) Determine consequences (impacts) of exposures to individual receptors according to established dose-response relationships in terms of excess risk of cancer or noncarcinogenic effects.

5) Characterize the overall risk in terms of human health consequences and potential environmental effects.

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Assumptions and Considerations of Uncertainty. TRU waste inventories are discussed in Appendix B. Risk assessments assume that the maximum design basis quantity of waste would be shipped to the WIPP. During the Test Phase, estimates are based on the equivalent of 88,000 drums (620,000 ft^3) of CH waste or an average of 17,600 55-gal drum equivalents per year. (It was assumed that 10 percent of the projected CH waste from all facilities would be sent to the WIPP during the Test Phase. Although it is recognized this scenario is extremely unlikely, the assumption provides an upper bound of the estimated risks). The estimate used for the subsequent 20-year Disposal Phase is the equivalent of 39,600 drums per year (5.58 million ft^3) of CH waste and 7,953 RH canisters (250,000 ft^3) giving a total estimated volume of waste to WIPP of 6.45 million ft^3. This volume of post-1970 TRU waste is not currently projected to exist or be generated over the next 25 years. However, SEIS analyses are based on this maximum design capacity of the WIPP to provide an upper bound on estimates of potential impacts.

To compensate for uncertainties, the overall risk assessments are biased toward health protection. For example, an off-site exposed individual was assumed to be present at the point of maximum off-site concentration. This is highly improbable and overestimates risks.

This conservative approach compensates for possible uncertainties in the risk assessment process and does not provide a "most-likely-to-occur" scenario. Unless the conservative assumptions postulated in these scenarios are true, the risks will be overestimated. If effects associated with these conservative scenarios pose no risks to workers or residential populations, it follows that less conservative scenarios associated with decreased exposures also pose low risks.

5.2.3.2 Radiological Risk Assessment Methodology. This subsection provides an overview of the methods and assumptions used to estimate potential radiological exposures (dose estimates) during WIPP operations, including unloading, handling, underground emplacement, and assumed waste retrieval activities, considering both routine operations and reasonably foreseeable accident scenarios. An overview of the AIRDOS-EPA computer model, used to evaluate releases to the air, and the assumptions used to estimate potential effects of radiological releases on human health and the environment are provided in Appendix F.

Radiological dose assessments and methodologies used in this SEIS are primarily based on the analyses in the WIPP draft FSAR (DOE, 1989b). Differences between dose assessment methods and assumptions used in the FEIS and this SEIS are examined. Differences between radiation doses reported in the FEIS and current estimates result from refinements in inventory characterization, modifications to the facility and waste handling operations, and changes in dose modeling methodology.

Risk assessments of WIPP operations have been periodically updated since the FEIS, primarily through amendments to the FSAR. As discussed below, better characterization of waste inventories, facility design refinements, development of more realistic accident and routine release scenarios, and modifications of dose assessment models have resulted in refinements of the WIPP risk estimates.

Dose Models. The FEIS (DOE, 1980) used a modified version of the computer code AIRDOS-II to calculate doses at the WIPP from routine and accident operations. AIRDOS-EPA, a modification of AIRDOS-II, is used for current risk assessments.

The FEIS calculated individual organ dose commitments to the whole body, lungs, and bone. The SEIS calculates radiation exposure in terms of committed effective dose equivalents (CEDE), the expression of dose in use today. Both the FEIS and this SEIS use a 50-year dose integration period, i.e., that dose which occurs over a 50-year period following exposure because of retention of radionuclides in the body from the ingestion or inhalation of radioactive materials. The use of effective dose equivalent (EDE) rather than organ doses provides a more conservative basis for estimating risk and regulatory compliance because the EDE incorporates dose contributions from all significant exposed organs.

The FEIS used internal dose conversion models recommended by the Nuclear Regulatory Commission (NRC, 1977). Internal dose conversion factors used in current calculations are provided by Dunning (DOE, 1985) and are based on the International Commission on Radiological Protection recommendations and models (ICRP 1977; ICRP 1979) which were endorsed by DOE Order 5480.11 (DOE, 1988a) and draft DOE Order 5400.3 (DOE, 1988d).

Inventory and Source-Term Changes. Since the FEIS, more accurate knowledge of waste composition and volumes at the generator facilities has been gained (see Appendix B). Experiments with high-level waste have been deleted from the WIPP project mission. Increased quantities of high-neutron waste are projected from Oak Ridge National Laboratory. Current projections of numbers of shipments and waste volumes also differ from those in the FEIS because of changes to the transport container capacity and the definition of what constitutes TRU waste. For bounding purposes, all impacts in the SEIS have been assessed based on the current maximum design capacity of 6.45 million ft^3 of waste even though less inventory of TRU waste is now estimated.

Current dose assessments are based on Plutonium-239 Equivalent Curie (PE-Ci) Activity instead of the specific radionuclide distribution utilized in the FEIS. The PE-Ci eliminates the dependency of radiological analyses of inhalation risks on knowledge of the specific radionuclide composition of each TRU waste stream. Instead, radionuclides are normalized to a common radiotoxic hazard index, that of plutonium-239. Further discussion of the PE-Ci concept is provided in Appendix F.

Accident Scenarios. Current accident scenarios differ from those evaluated in the FEIS (Subsection 9.5) due to facility design changes and the refinement of assumptions describing reasonably foreseeable events, "material at risk" (related to changes in projected inventories and source-terms), and release mechanisms. Accident scenarios in the FEIS assumed that HEPA filters in both the waste handling building and the underground exhaust systems function properly and mitigate atmospheric releases by a factor of 1×10^6. The SEIS conservatively assesses the impacts associated with unfiltered accidental releases from the underground (the impacts from the underground scenarios bound those from the waste handling building).

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The FEIS postulated 22 accidents involving CH waste and 21 accidents involving RH waste. Scenarios involving a surface fire, surface container failure, underground container failure (hoist drop), and an underground fire involving waste were evaluated because they were postulated to represent the most serious accidents for their respective waste categories. The FEIS determined that the "worst-case" accident was an underground fire involving 90 drums. As discussed in Appendix F (accident description C9) engineering modifications have considerably reduced the likelihood of this accident and it is no longer considered a reasonably foreseeable event.

The SEIS postulates 11 accidents involving CH waste and 6 accidents involving RH waste (Appendix F). Specific accident scenarios which are unique to the Test Phase have not been identified that would not be bounded by those for the Disposal Phase analysis. The maximum credible accident involves a fire in a drum stored underground. A "beyond design basis" accident involving a hoist system failure has also been assessed as a highly improbable but potentially severe accident event at the WIPP. (Such an event has been estimated to occur once in 60 million years of operation.)

Model Input Parameters. Several of the FEIS input parameters are different than those used in current assessments. Estimated flow velocities, diameters, heights, and locations for the stacks are different, and facility air change rates have changed since the FEIS. Also, demographic data for the WIPP area have been updated for the current assessments. Demographic data affect the population at risk in the model and the significance of particular pathways to man. The newer data indicate more people but fewer milk and beef cattle than were assumed in the FEIS calculations.

The FEIS calculated a routine dose commitment to a person living at the residence nearest the WIPP site and a population dose for persons residing within a 50-mile radius of the site. For accident purposes, the FEIS exposed individual was a member of the public assumed to reside at an existing residence near the WIPP site boundary. Conservative meteorological conditions were assumed to overestimate the likely exposure. This SEIS calculates a routine dose commitment to a hypothetical individual assumed to be living at the WIPP site boundary at the point where the maximum assumed exposure would occur and to the total population of about 113,000 people living within a 50-mile radius. For the current accident analyses, doses are calculated to a hypothetical individual located within the WIPP site but beyond the secured area fence where the dose model projects the maximum exposure (maximum individual), and to the exposed public in the surrounding area.

Migration Pathways. Potential pathways for radionuclide release from the WIPP include air, ground and surface waters, and soil. Each medium is evaluated as a migration pathway for waste-related radionuclides. It was determined in the draft FSAR that the air pathway is the only significant biosphere release and exposure pathway from the WIPP during operations. Secondary pathways include ingestion of contaminated food and water and immersion in contaminated water, all of which could result from the deposition of airborne radioactive particulates.

Air Pathway. Vapors and suspended particulates may be dispersed through the air due to off-gassing from the waste drums, from the release of assumed contamination on the outside surface of the drums, from accidental spill, or as a result of a fire.

If a release occurs, the air transport pathway presents the most rapid and pervasive dispersion mechanism, whether the release occurs above- or belowground. Deposition of radioactive particulates from airborne releases may also result in contamination of soils and surface water. The contribution of surface contamination to total radiological exposure is included in the AIRDOS-EPA model.

Based on extensive WIPP site characterization data and analyses performed for the draft FSAR, airborne releases are identified as the principal potential environmental pathway. For routine operations, air concentrations and surface deposition levels are calculated, using annual average site meteorologic conditions and postulated airborne releases, in all directions and at various distances from the WIPP. Radiological exposures to members of the public are calculated by summing the exposures from all potential pathways.

Accidental releases are assessed similarly, except that accident scenarios assume stable meteorological conditions which allow little dispersion of the release in order to estimate a maximum resulting hypothetical dose-to-people. The hypothetical maximally exposed individual for accident assessments is assumed to remain at the center-line of the release plume for the duration of each postulated accident. For the purpose of calculating accident-related population dose, annual average meterological conditions (wind speed and stability class frequency distribution) for a constant wind direction towards the direction (in this case west) which maximizes the collective population impacts.

Liquid Pathway. Liquid releases directly to ground water or surface water operations are not credible. Waste handling operations are conducted inside the waste handling building or the underground repository. The waste does not contain free liquids. Any liquids containing radioactive materials that may be generated from on-site operations will be contained, collected, and solidified in the waste handling building. As such, no radioactive liquids are available for release during the operating life of the facility.

Pathways to surface water are not present even in the presence of any liquid waste effluents from the WIPP site. No major surface-water bodies exist within a 10-mile radius of the WIPP facility. The Pecos River is located 14 miles west of the site. The WIPP surface structures are approximately 500 ft above the river bed and over 400 ft above the 100-year flood plain.

Soil Pathway. A third pathway commonly considered in risk assessments is through direct releases to soil. All WIPP waste is containerized, handled within the waste handling building and emplaced in rooms mined 2,150 ft below the ground surface. By the nature of the operations, there is no credible mechanism for direct release to soil.

Dose Calculation Modeling. This SEIS and the FEIS identify release of airborne radioactive particulates from the waste handling building and the underground ventilation exhaust shaft as the most significant migration pathway arising from WIPP operations. A modified version of the computer code AIRDOS-II was used to calculate doses from radionuclide releases reported in the FEIS. AIRDOS-EPA, a modification of the AIRDOS-II computer code model (Moore et al., 1979), is used in current analyses to estimate off-site environmental concentrations and radiation doses associated with

the atmospheric release of radionuclides in routine and accidental release assessments. Most of the input parameters which characterize the area surrounding the site or the radionuclides released are identical for routine and accidental releases. Other input, such as the amount of radioactivity released (the source term) and the meteorological assumptions, are specific to the release scenario. An overview of AIRDOS-EPA is included in Appendix F.

The AIRDOS-EPA computer code estimates the radiation dose to man due to the postulated atmospheric release of radionuclides from the WIPP. The area surrounding the site is modeled as a 50-mile radius circular grid system with the release point located at the center. For routine release assessment, annual average meteorological conditions are used to calculate exposures to the 50-mile radius population and to a theoretically maximally exposed individual.

For accidental exposure assessment, meteorological conditions are artificially constrained to result in a maximum dose to a hypothetical individual assumed to be located within the WIPP site boundary but beyond the secured area fence. These meteorological conditions (windspeed, atmospheric stability class, and direction) are assumed to prevail for the duration of the accident and plume spread of the release is limited to a 22.5° sector. The ground-level concentration of airborne radioactivity at the center-line of the plume is used for the accident assessment for the maximum individual. For accidental exposure assessment to the population, wind direction is constrained to the direction that results in maximum consequence, due west, but annual average meterological conditions for that direction are assumed to exist. These annual average conditions include the full range of possible combinations of stability class and wind speed. Because of the relatively long plume travel time to the closest population centers, it is very improbable that the same meterological conditions used for the maximum individual assessment would prevail over a 50-mile travel distance. The sector average ground-level concentration is used for the accident assessment for the population.

Estimates of routine and accidental radiological releases and subsequent dose calculations for projected WIPP operations are extrapolated from the draft FSAR (DOE, 1989b). As discussed above, calculations of radiological releases in the draft FSAR use source terms expressed as PE-Ci rather than specific radionuclide activities as used in the FEIS. Since there are no liquid release pathways from the site during operations, all releases evaluated for the WIPP, both routine and accident-related, are assumed to be airborne.

In assessing the radiological impacts of routine operations and accident scenarios, all particulates released from the waste handling building pass through HEPA filters and are assumed to be of a respirable size. The respirable range is represented by a particle with a 1.0-micron, aerodynamic-equivalent diameter (AED) and a HEPA filter removal efficiency of 99.9 percent is assigned to each HEPA filter stage. This is a conservative assumption, since these filters are designed to remove even smaller particles, 0.3 micron AED, at an efficiency of 99.97 percent. Releases from the underground disposal area are not filtered during routine operations since the filters are bypassed to prevent clogging with salt dust. In the event that a release is detected underground, all underground ventilation exhaust is designed to pass through two

HEPA filters in series. However, in an attempt to bound the reasonably foreseeable impacts of the Proposed Action, the ventilation system filtration mode is assumed not to activate, resulting in an unfiltered release.

Ecological Consequences of Radiological Impacts. Radiological releases can also impact terrestrial and aquatic ecosystems. Exposures from estimated radiological releases to the ecosystem are compared to background levels to determine incremental increases. If releases and exposures are within naturally occurring variations in background radiation levels, the impacts of the releases on the ecosystem will not be measurable. In general, ecosystem species, particularly plants, can endure higher exposures than those determined for human health protection.

Waste Retrieval. The FEIS (Subsection 8.10) did not provide a quantitative dose assessment of waste retrieval. In 1987, a mock retrieval demonstration for waste was performed at the WIPP using similar but non-radioactive containers to simulate CH TRU waste. The retrieval demonstration plan and a time-line dose assessment based on video recordings of the mock-up retrieval were documented in WEC (1988a).

Routine retrieval operations involving both drummed and boxed waste were simulated in the demonstration. Although container failures are not expected during the Test Phase, potential radiation exposure estimates for failed and contaminated container retrieval were also obtained by evaluating retrieval and overpacking operations. The mock-up data were used to calculate the average crew dose per container for clean and contaminated boxes and drums. This crew dose was divided by the number of workers (16 waste handlers and 8 health physics technicians) to obtain an average worker dose for retrieval of containers. Dose impacts associated with retrieval were evaluated for retrieval of clean containers and for a scenario where 5 percent of the containers were contaminated. (Waste receipt and emplacement operations are assumed to result in release of the preexisting surface contamination). Estimated retrieval doses were based on receipt of 10 percent of the total waste volume during the 5-year Test Phase. Public risk estimates for waste retrieval activities assume the waste containers remain intact throughout the Test Phase and the subsequent retrieval period.

The same potential accident types considered in the Test and Disposal Phases of WIPP are equally applicable to retrieval operations. These may result from either human error or equipment failure. Although the magnitude and consequences of potential accidents are anticipated to be similar to those possible during other phases of operation, the likelihood of a container failure accident may be somewhat higher depending upon waste container condition at the time of retrieval. In addition, retrieval of waste from back-filled rooms may be more complex resulting in a higher probability of an accident during retrieval operations. Waste containers are designed to remain intact for 20 years and will be emplaced in such a way as to minimize the probability of failure due to repository conditions (see Appendix O).

If a decision to retrieve waste is made at the end of the Test Phase, a contamination control area would be established in waste retrieval chambers during waste retrieval operations. Airflow in the control area would be maintained such that workers remain upstream of the working face of the waste stack. Current plans are to continuously

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filter area exhausts through a single HEPA filter, reducing the concentration of particulates released to the underground disposal exhaust shaft by a factor of 1,000 before release to the atmosphere.

5.2.3.3 Routine Operational Radiological Releases and Exposures. Routine releases of radionuclides to air and resultant radiological exposures to workers and the public are discussed in this subsection. Possible public health and ecological consequences from such routine releases are evaluated in Subsection 5.2.3.5. Exposures are based on inhalation and direct exposure pathways as well as secondary pathways resulting from deposited material. These secondary pathways include consumption of contaminated food and immersion in contaminated water.

Routine Radiological Releases During Facility Operations. Routine Releases–Proposed Action. Small amounts of radioactivity may be released during normal handling and storage operations. Potentially contaminated air will be exhausted from the waste handling building and the exhaust shaft. Releases during routine operation are estimated using the current WIPP design (DOE, 1989b). Radioactive releases during the normal waste handling are estimated using an equivalent throughput of 17,000 drums per year (i.e., a projected 10 percent of the design capacity during the Test Phase) and assuming a throughput of approximately 39,600 drum equivalents of CH TRU waste and 400 canisters of RH TRU waste annually during the subsequent 20-year Disposal Phase.

The waste handling building exhaust will be continuously filtered through two stages of HEPA filters. The underground exhaust flows through HEPA filters only when air monitors in the waste disposal area or the exhaust detect airborne radioactivity in excess of preset limits.

Surface contamination levels on waste containers may vary significantly. The current WIPP Waste Acceptance Criteria permit surface contamination levels of up to 50 pCi/100 cm^2 of alpha-emitting radionuclides and 450 pCi/100 cm^2 of beta/gamma-emitting radionuclides. These overall levels of surface contamination are permissible under Department of Transportation regulations. However, the retrieval program at the Idaho National Engineering Laboratory indicates that most retrievably stored drums are free of surface contaminants (McKinley and McKinney, 1978). To be conservative, the draft FSAR upon which this SEIS assessment was based assumes that 10 percent of all drums and boxes received at the WIPP have the maximum permitted level of surface contamination. The draft FSAR assessment used a resuspension factor of 1×10^{-5}/m, as recommended by Sutter (1982), to account for resuspension of surface containments. The SEIS assumes that 100 percent of the waste container surface contamination is released as a result of handling, 50 percent within the waste handling building and 50 percent in the underground disposal area. This assumption couples the quantity available for release to that which is assumed to be released.

Drums and boxes require inspection for possible damage before shipment to WIPP because only undamaged containers may be shipped. However, this risk assessment assumes that 0.1 percent of the drums and boxes received are damaged and release one percent of their content into the waste handling building when the shipping containers are opened. The analysis assumes that the airborne activity will be

generated during one shift, 250 days per year, and that 0.1 percent of the spilled material is resuspended, 5 percent of which is in the form of radioactive particulates.

RH waste canisters (about 400 per year) will be decontaminated before shipment to the WIPP. However, the current risk assessment conservatively assumes that, upon receipt at the WIPP, 10 percent of the canisters carry surface contaminants at the maximum level permitted by the Waste Acceptance Criteria. It is further assumed that 50 percent of this canister surface contamination is released within the waste handling building and 50 percent within the underground disposal area. It is postulated that 0.1 percent of the RH TRU waste canisters per year (at least one) are defective upon arrival at the WIPP, and, that 1 percent of their content is released in the hot cell before the defective canister is overpacked. Of this 1 percent, 0.1 percent is resuspended, 5 percent of which is in the form of radioactive particulates.

Using the projected composition of waste identified above, and assuming 99.9999 percent removal efficiency by the two-stage HEPA filters in the waste handling building and no filtration of underground releases, the calculated annual average releases to the atmosphere from the WIPP are shown in Table 5.22.

Routine Exposures - Proposed Action. As discussed previously, airborne release of radioactivity is the only significant pathway of exposure to the public. The release quantities provided in Table 5.22 (for Alternative Action, see Table 5.51) and average annual meteorological conditions are used to calculate potential exposures to members of the public from routine WIPP operations. Annual radiation exposures are estimated to the population within 80 kilometers (50 miles) of the WIPP facility and to a maximally exposed offsite individual at the point of highest annual average air concentration at or beyond the WIPP-site boundary. The FEIS assumed the maximally exposed individual was located at a further distance, the nearest residence, Mills (James) Ranch. Dose estimates to members of the public are included in Table 5.23 (for Alternative Action, see Table 5.52).

Table 5.23 (for Alternative Action, see Table 5.52) indicates that routine operations could result in about 1.5×10^{-6} and 3.5×10^{-6} rem/year committed effective dose equivalent to the maximally exposed adult individual during the Test and Disposal Phases, respectively. These individual doses are considerably less than limits established by the EPA of 1.0×10^{-2} rem/yr in 40 CFR Part 61. Population doses are calculated to be 4.7×10^{-4} and 1.1×10^{-3} person-rem/year collective committed effective dose equivalent (50-year dose commitment). Both the maximum individual and the total population dose are compared in Table 5.23 (for Alternative Action, see Table 5.52) to the dose which occurs from naturally occurring "background radiation."

Radiation exposure to workers may result from direct (external) radiation and from inhalation of contaminated particles. The facility is designed to meet the DOE goal of limiting occupational exposure to 20 percent of regulatory standards as stated in DOE Order 5480.11 (DOE, 1988a). Also, administrative controls, such as personal dosimetry, health physics surveys and radiation protection procedures, together with the use of protective clothing and respiratory protection when needed, will reduce radiation exposure to individual workers to as low as reasonably achievable within the DOE limit of five rem (0.05 sievert) per year (DOE, 1988a). External radiation dose estimates are

TABLE 5.22 Routine radionuclide releases to the WIPP environment during the Proposed Action (total activity in curies/year)

	Test Phase[a]		Disposal Phase[b]	
Radionuclide	WHB[c]	SE[d]	WHB	SE
Co-60	0[e]	0	7.1×10^{-14}	3.7×10^{-8}
Sr-90	0	0	2.1×10^{-12}	1.1×10^{-6}
Ru-106	0	0	1.5×10^{-14}	7.7×10^{-9}
Sb-125	0	0	4.6×10^{-16}	2.4×10^{-10}
Cs-137	0	0	1.8×10^{-12}	9.4×10^{-7}
Ce-144	0	0	1.4×10^{-13}	7.5×10^{-8}
Th-232	6.3×10^{-18}	4.9×10^{-13}	1.4×10^{-17}	1.1×10^{-12}
U-233	1.6×10^{-13}	1.3×10^{-8}	3.7×10^{-13}	2.9×10^{-8}
U-235	8.9×10^{-18}	1.2×10^{-12}	8.7×10^{-16}	2.5×10^{-10}
U-238	3.3×10^{-17}	2.6×10^{-12}	4.4×10^{-16}	7.5×10^{-11}
Np-237	2.1×10^{-16}	2.1×10^{-11}	4.8×10^{-16}	4.8×10^{-11}
Pu-238	1.0×10^{-10}	8.2×10^{-6}	2.4×10^{-10}	1.9×10^{-5}
Pu-239	8.1×10^{-12}	6.3×10^{-7}	2.0×10^{-11}	1.7×10^{-6}
Pu-240	1.8×10^{-12}	1.4×10^{-7}	4.6×10^{-12}	4.2×10^{-7}
Pu-241	1.5×10^{-10}	9.2×10^{-5}	3.5×10^{-10}	2.1×10^{-4}
Pu-242	3.0×10^{-16}	2.3×10^{-11}	7.6×10^{-16}	6.9×10^{-11}
Am-241	1.7×10^{-11}	1.8×10^{-6}	3.8×10^{-11}	4.0×10^{-6}
Cm-244	3.2×10^{-13}	2.5×10^{-8}	7.7×10^{-13}	6.4×10^{-8}
Cf-252	5.1×10^{-14}	3.9×10^{-9}	1.8×10^{-13}	2.1×10^{-8}
Total	2.8×10^{-10}	1.0×10^{-4}	6.5×10^{-10}	2.4×10^{-4}

[a] Based on annual throughput equivalent to about 17,600 CH drums.
[b] Based on annual throughput equivalent to about 39,600 CH drums and 400 RH canisters.
[c] WHB = waste handling building.
[d] SE = storage exhaust.
[e] No release because no RH waste will be used in the Test Phase.

consistent with the draft FSAR. Internal radiation dose estimates are based upon the equilibrium air concentrations in the waste handling building and underground disposal area working environments, consistent with Table 5.22 (for Alternative Action, see Table 5.51). (The waste handling crew is assumed to spend half of their time in each of the two areas.) Annual occupational exposure estimates to the work force are provided in Table 5.24 (for Alternative Action, see Table 5.53).

Routine Waste Retrieval Releases and Exposures. If the decision is made to retrieve the emplaced TRU wastes, there will be external radiation exposure to workers and a potential for an airborne radiological release. Airborne releases are not anticipated because waste containers are designed to maintain their structural integrity for at least 20 years. Occupational exposures were estimated from video recordings made during the mock retrieval demonstration for CH TRU waste (WEC, 1988a). Time-line studies estimated length of exposures and total doses. Potential doses were determined for the total work crew and for an average individual worker with the resultant dose assumed to occur over the retrieval period.

The mock-up evaluation also estimated doses due to handling waste containers with surface contamination. No mechanism for the contamination of waste container

TABLE 5.23 Annual radiation exposure to the public from routine operations during the Proposed Action

Activity	Test Phase	Disposal Phase
Population[a] (person-rem)	4.7×10^{-4}	1.1×10^{-3}
Population background (person-rem)	1.1×10^{4}	1.1×10^{4}
Maximum[b] individual (rem)	1.5×10^{-6}	3.5×10^{-6}
Individual background (rem)	1.0×10^{-1}	1.0×10^{-1}

[a] 50-year committed effective dose equivalent to population within 50 miles.
[b] 50-year committed effective dose equivalent at point of maximum air concentration.

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TABLE 5.24 Annual occupational radiation exposure[a] from routine operations during the Proposed Action (person-rem/year)

Activity	Test Phase	Disposal Phase
Direct radiation	6.3	14.3
Inhalation of airborne contaminants[b]	1.1	2.5
Total	7.4	16.8

[a] Exposures are total exposures to the entire waste handling crew.
[b] 50-year committed effective dose equivalent for one year of exposure.

surfaces during storage has been identified. However, consistent with the assumptions made in the dose assessments for facility operations, it is assumed that a percentage of the waste containers were found to be contaminated and require overpacking. This percentage is set at five percent. (Prior assumptions assume that all preexisting surface contamination is released during initial emplacement.) Estimated occupational exposures for waste retrieval activities are shown in Table 5.25.

The exposure to an individual receiving the maximum off-site exposure as a result of retrieval operations is calculated in the same manner as for waste emplacement. However, annual releases associated with retrieval are less than those associated with routine emplacement because the retrieval process is projected to require longer than emplacement and releases would be reduced by a factor of 1,000 due to the HEPA filtration to be used in the contamination control area. These exposure estimates are also very low, as shown in Table 5.25.

5.2.3.4 Accidental Radiological Releases and Exposures. This subsection assesses the potential radiological releases and exposures associated with postulated accident scenarios for WIPP operations. Accident scenarios are formulated and evaluated to assess their potential consequences. Environmental and health consequences of postulated accidents are in this subsection. Most of the accidents during the WIPP's operating lifetime are expected to be industrial in nature, not resulting in releases of radioactive material. Only those with the potential to release radioactive material are discussed below.

Operational accident scenarios were developed and analyzed in both the FEIS (Subsection 9.5) and this document (Appendix F). The FEIS assessment included several accident scenarios involving both CH and RH waste. Of these accident scenarios, four involving CH and two involving RH waste were assumed to be "limiting" and were analyzed in detail. This SEIS analyzes 11 CH and 6 RH waste accident scenarios as described in Appendix F of this SEIS.

Projected Accidental Releases. The accident scenarios were formulated from an examination of WIPP process operations, design basis inventories, and controls of radiological/hazardous materials. No pathways were identified whereby accidental releases of liquids to the environment might occur. Airborne release is the only significant pathway for accidental exposure to the public. Accidental releases of soluble and insoluble forms of waste constituents were assessed.

Accident scenarios are developed by following the course of a typical waste container from off-loading in the waste handling building receiving area to final storage in the waste disposal area, and by reviewing waste handling procedures. The normal operation of waste handling equipment, such as forklifts and hoists, was studied to determine how equipment misuse or failure could result in a breach of the waste containers. Tables 5.26 and 5.27 list accident scenarios for this SEIS and their frequencies for CH and RH waste handling activities, respectively.

The frequency category of an event was derived from the operating experience of similar facilities when such data are available. Conservative engineering judgment was

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TABLE 5.25 Estimated occupational and off-site radiation exposures for routine CH waste retrieval activities[a]

	Case I[b]	Case II[c]	
	Clean drums	95% Clean drums	5% Contaminated drums
Average crew dose/container (mrem)	0.7	0.7	1.7
Total number of containers	88,000	83,600	4,400
Total crew	24	24	24
Total crew dose (person-rem)	62	59	7.5
Average dose/worker (mrem per year)[d]	250	240	31
Maximum offsite individual dose (rem per year)[e]	-----	-----	3.8×10^{-10}
Off-site population dose (person-rem per year)	-----	-----	1.2×10^{-7}

[a] McKinley and McKinney, 1978.
[b] Case I assumes all drums are free of surface contamination.
[c] Case II assumes 95 percent of drums are free of surface contaminants and 5 percent of drums have developed surface contamination at levels permitted by the Waste Acceptance Criteria.
[d] Average millirem per year for each of 10 years.
[e] Average 50-year committed effective dose equivalent for each of 10 years to a maximally individual located at the site boundary, assuming one half of the release rate and one half of the total release as postulated for routine emplacement operations (release is further mitigated by on-line HEPA filtration).

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TABLE 5.26 Accident scenarios involving CH waste[a]

Area	Accident ID	Estimated frequency	Possible accident scenario
Radiological control area outside of WHB	CO	MF	TRUPACT-II drops from transporter
Off-loading/loading	C1	MF	Vehicle collision in off-loading area
Inventory/preparation	C2[b]	MF/LIM	Drum dropped from forklift
	C3[b]	MF/LIM	Drum punctured by forklift
Underground disposal	C4[b]	MF/LIM	Transporter hits pallet
	C5[b]	MF/LIM	Drum dropped from forklift
	C6[b]	MF/LIM	Drum punctured by forklift or other equipment
Inventory/preparation	C7	LIM(NE)	Spontaneous ignition within a drum
Hoist loading areas	C8	LIM(BDB)	A loaded hoist cage drops down waste handling shaft
Underground disposal	C9	LIM(NE)	Diesel fire in disposal array underground
	C10	LIM	Spontaneous ignition within a drum

MF = Moderate Frequency (assumed to occur annually).
INF = Infrequent (assumed to occur once during the life of the facility).
LIM = Limiting (assumed not likely to occur during the life of the facility).
NE = Not evaluated (offsite impacts of C7 bounded by C10; equipment design features preclude C9)
BDB = Beyond design basis accident per DOE policy (DOE, 1988e).

[a] Source: draft FSAR (DOE, 1989b).

[b] Moderate frequency for average drum content. Limiting if drum(s) contain 100 PE-Ci or 1000 PE-Ci.

TABLE 5.27 Accident scenarios involving RH waste[a]

Area	Accident ID	Estimated frequency	Possible accident scenario
Receiving	R1	MF	Crane strikes shipping cask
	R2	INF	Shipping cask drops from crane
	R3	INF	Shipping cask drops in the cask preparation area
Hot cell	R4	INF	RH waste canister drops from hot cell into transfer cell
Hoist cage loading area	R5	LIM(BDB)	A loaded hoist cage drops down waste handling shaft with a canister of RH TRU waste
Underground	R6	LIM	Fire in RH waste disposal area

MF = Moderate Frequency (assumed to occur annually).
INF = Infrequent (assumed to occur once during the life of the facility).
LIM = Limiting (assumed not likely to occur during the life of the facility).
BDB = Beyond design basis accident per DOE policy (DOE, 1988e).

[a] Source: draft FSAR (DOE, 1989b).

used to classify events if relevant historical information was not available. Incidents of moderate frequency are those assumed to occur once a year. Infrequent incidents are those assumed to occur once during the operation of the WIPP and are within the design basis for the facility. Limiting incidents were those that are not expected to occur during the life of the facility, but were included in the analysis to bound the reasonably foreseeable release of radioactivity from a low probability accident having potentially severe consequences. (Accidents whose probability of occurrence is less than 1×10^{-6} per year are beyond the design basis for the facility per DOE Order 6430.1A (DOE, 1988e). As such, design considerations need not consider these extremely low probability accidents.)

The source terms used in the analyses were based on the inventory information discussed in SEIS Appendix B. For events of moderate frequency (i.e., those projected to occur once per year), the average radionuclide content of the waste package was assumed to be available for release. For limiting accidents, the maximum allowable curie content of a waste package (1,000 PE-Ci) was assumed available for release. The WIPP WAC limit the maximum amount of respirable particulates (those less than 10 microns in diameter) in a waste container to one percent by weight. However, to ensure conservatism when dealing with a single or few containers, this respirable fraction was assumed to contain 5 percent of the waste's radioactivity. Furthermore, due to the lack of specific information concerning the particle size distribution, an activity median aerodynamic diameter of 1.0 micron has been assumed. Detailed accident descriptions and assumptions about releases are provided in Appendix F. Table 5.28 shows projected releases from accidents postulated in the SEIS. Underground releases in the FEIS were assumed to be reduced by a HEPA filter system having a removal efficiency factor of 1×10^{6}. For conservatism, data in Table 5.28 do not assume releases from the underground repository will be filtered prior to release to the atmosphere. Credit was taken for filtration (a factor of 1×10^{6}) of accident-related releases from the waste handling building in both the FEIS and SEIS since no common mode failure of both a waste container and the continuous on-line HEPA filtration system could be identified.

<u>Projected Accidental Exposures: Proposed Action</u>. Exposures are assessed in terms of the radiation dose to an exposed individual. The individual receptor for occupational dose is a worker near the accident, while the individual for public exposure is assumed to be located outside of the secured area fence but within the WIPP-site boundary.

Occupational exposure estimates are also provided in Table 5.28. They are conservatively estimated, since workers will normally be located in the "up-stream" airflow of a waste handling area. Operational procedures require that workers wear respiratory protection at all times when handling waste containers that hold greater than 100 PE-Ci of waste. The maximum exposure to a single worker is estimated to be 6.1 rem. Although no accidental dose limits are defined for occupational workers, this maximum dose to a worker is well within DOE guidance established for limiting accident exposure to individual members of the public (DOE, 1988d). Workers will be trained to respond to any unusual occurrence by leaving the area immediately and reporting the event so that accident-related exposures will be minimized and to ensure that evaluation and cleanup can begin promptly.

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TABLE 5.28 Radiation releases and exposures from credible accident scenarios during WIPP facility operation

Accident description	Release (Curies[a,b])	Maximally exposed worker (rem)	Maximally exposed individual[a,c] (rem)	General population[a,d] (person-rem)
SEIS[e]				
C2 WHB[f], average drum, drop, CH	1.6×10^{-10}	7.2×10^{-1}	5.6×10^{-10}	7.7×10^{-8}
WHB, 100 PE-Ci drum, drop, CH	1.3×10^{-9}	5.6×10^{0}	4.3×10^{-9}	6.2×10^{-7}
WHB, 1000 PE-Ci drum, drop, CH	1.3×10^{-8}	1.1×10^{0}	4.3×10^{-8}	6.2×10^{-6}
C3 WHB, 3 average drums, breach, CH	2.9×10^{-10}	1.3×10^{0}	1.0×10^{-9}	1.4×10^{-7}
WHB, 100 PE-Ci & 2 average drums, breach, CH	1.4×10^{-9}	6.1×10^{0}	4.8×10^{-9}	6.7×10^{-7}
WHB, 1000 PE-Ci & 2 average drums, breach, CH	1.3×10^{-8}	1.1×10^{0}	4.4×10^{-8}	6.2×10^{-6}
C4 UG[g], average drum, drop, CH	1.3×10^{-4}	4.5×10^{-1}	4.6×10^{-4}	7.0×10^{-2}
UG, 100 PE-Ci drum, drop, CH	1.0×10^{-3}	3.5×10^{0}	3.6×10^{-3}	5.4×10^{-1}
UG, 1000 PE-Ci drum, drop, CH	1.0×10^{-2}	7.0×10^{-1}	3.6×10^{-2}	5.4
C6 UG, 3 average drums, breach, CH	2.3×10^{-4}	8.1×10^{-1}	8.1×10^{-4}	1.2×10^{-1}
UG, 100 PE-Ci & 2 average drums, breach, CH	1.1×10^{-3}	3.8×10^{0}	3.8×10^{-3}	5.9×10^{-1}
UG, 1000 PE-Ci & 2 average drums, breach, CH	1.0×10^{-2}	7.0×10^{-1}	3.5×10^{-2}	5.4
C10 UG, 1000 PE-Ci drum, ignition, CH	5.0×10^{-1}	None	1.7×10^{0}	2.7×10^{2}
R4 WHB, hot cell 1000 PE-Ci canister, drop, RH	5.0×10^{-10}	None	1.8×10^{-9}	2.4×10^{-7}

[a] SEIS estimated releases and exposures due to underground scenarios do not take credit for HEPA filters and are therefore not reduced by a factor of 1×10^{6} as was done for the FEIS.
[b] SEIS releases are expressed as PE-Ci.
[c] Located on WIPP site beyond secured area fence.
[d] Located mainly west of the WIPP site.
[e] Extrapolated or taken from draft FSAR, Tables 7.3-1 and 7.3-2 (DOE, 1989b).
[f] WHB = Waste Handling Building.
[g] UG = Underground Storage Area.

Dose to an individual located outside the facility boundary (aboveground and away from the physical location of the postulated accident) is also assessed. An accidental exposure to radioactivity can occur via three major routes: inhalation of contaminated air, external exposure from immersion in contaminated air, and exposure from contaminated ground surfaces. Less important routes for the radionuclides under consideration include ingestion of contaminated food and water and immersion in contaminated water. The maximum accident exposure to an offsite individual is estimated in the SEIS to be 1.7 rem. The maximum estimated accident exposure to the offsite population is 270 person-rem.

Because of commenters' concerns (particularly the Environmental Evaluation Group), a beyond design basis accident has also been assessed and incorporated in this SEIS. A catastrophic hoist system failure, estimated to occur once in 60 million years, initiates the scenario. As discussed in Appendix F.3, a set of assumptions which describes the details of the accident must then be made to calculate the resulting impact. These assumptions include the size of the radioactive payload, the amount of material released, and the fraction of that material which is respirable, whether the HEPA filter system activates, the location of the maximally exposed individual, and the meteorological conditions at the time of the accident. The specific assumptions are critical in estimating the consequences of the accident. Generally, the more conservative the assumptions, the more severe the estimated consequences but the less likely the scenario is to occur.

Appendix F.3 evaluates different sets of assumptions which indicate the dose to the maximally exposed individual could range from 190 rem for a very conservative scenario to 7 millirem for a more likely or "nominal" scenario. It is further estimated that the annual probability of these events occurring ranges from about 1×10^{-17} for the 190 rem to about 1×10^{-9} for the 7 millirem dose. The DOE does not consider the scenario to be reasonably foreseeable or the exposure risks from this postulated accident to be significant. (As previously indicated, design and operational considerations are not required to be made to mitigate the consequences of such low probability accidents.)

5.2.3.5 Human Health and Environmental Consequences of Radiological Releases. Estimated releases of and consequent exposures to radioactive materials in the TRU wastes are related to potential risks to human health and the environment. The FEIS calculated radiological exposures for human populations and discussed the potential health effects associated with those exposures. In the SEIS assessment, risks to human health are expressed as an increase in the risk of fatal cancers due to radiological exposure.

Consequences of Facility Operations. It is assumed that management and control systems operate as designed and that normal operations remain within established limits in the assessment of consequences related to routine operational releases and exposures resulting from WIPP operations. Human health risks presented in Tables 5.29 (for Alternative Action, see Table 5.54) and 5.30 (for Alternative Action, see Table 5.55) for routine and accidental exposures, respectively, are based on dose estimates discussed in SEIS Subsections 5.2.3.3 and 5.2.3.4. A discussion of risk estimation and

TABLE 5.29 Risks associated with routine radiological releases from WIPP operations during the Proposed Action[a,b,c]

Worker Population		
Activity	Test Phase	Disposal Phase
Facility operations	2.1×10^{-3}	4.7×10^{-3}
Waste retrieval[d]	1.7×10^{-3}	-----

Maximum Individual		
Activity	Test Phase	Disposal Phase
Facility operations	4.2×10^{-10}	9.8×10^{-10}
Waste retrieval[d]	1.1×10^{-13}	-----

General Population		
Activity	Test Phase	Disposal Phase
Facility operations	1.3×10^{-7}	3.1×10^{-7}
Waste retrieval[d]	3.3×10^{-11}	-----

[a] Health risks are expressed as the annual number of excess fatal cancers estimated in the entire exposed population as a result of WIPP-related activities. For perspective, the average lifetime risk of any single individual contracting a fatal cancer is 2.2×10^{-1}.

[b] Risk of contracting fatal cancer: 2.8×10^{-4} fatalities/person-rem for each year of operation (BEIR, 1980).

[c] Annual health effects risk estimates for genetic effects would be somewhat less than the numbers presented in the table for cancer fatality risks as discussed in Appendix N.

[d] Waste retrieval is estimated to take twice as long as emplacement. Population risks during routine retrieval are assumed to be mitigated by the use of HEPA filtered contamination control areas.

TABLE 5.30 Maximum worker, general population, and maximum individual risks associated with worst-credible, accidental radiological releases from the WIPP during the Proposed Action[a]

Maximum Worker[b,c,d]

Activity	Test Phase	Disposal Phase
Facility operations	1.7×10^{-3}	1.7×10^{-3}
Waste retrieval	1.7×10^{-3}	--
Current risk of fatal cancer	2.2×10^{-1}	2.2×10^{-1}

Maximum Individual[b,c,e,f]

Activity	Test Phase	Disposal Phase
Facility operations	4.8×10^{-4}	4.8×10^{-4}
Waste retrieval[g]	4.8×10^{-7}	--
Current risk of fatal cancer	2.2×10^{-1}	2.2×10^{-1}

General Population[c,f,h]

Activity	Test Phase	Disposal Phase
Facility operations	7.6×10^{-2}	7.6×10^{-2}
Waste retrieval[g]	7.6×10^{-2}	--
Current risk of fatal cancer	7.8×10^{2}	7.8×10^{2}

[a] Health effects risk estimates for genetic effects would be somewhat less than the numbers presented in the table for cancer fatality risks as discussed in Appendix N.

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[b] Health risks are expressed as the probability of an individual contracting a fatal cancer during his/her lifetime as a result of evaluated accidental exposures. Risks are expressed in exponential form; i.e., 1×10^{-4} is equivalent to 1 chance in 10,000.

[c] Risk of contracting fatal cancer: 2.8×10^{-4} fatalities/rem

[d] Draft FSAR accident C3.

[e] Within the site boundary at the secured area fence.

[f] Draft FSAR accident C10.

[g] Offsite risk is mitigated by the use of HEPA filtered contamination control areas.

[h] Health risks are expressed as the number of excess fatal cancers estimated in the entire exposed population of 35,500 located in the westerly direction (does not include the maximum individual).

regulatory guidance concerning risk levels is provided in SEIS Subsection 5.2.2.1 and Appendix N.

It is estimated that 2.1×10^{-3} and 4.7×10^{-3} excess fatal cancers per year will occur in the exposed worker population at the WIPP site from routine operations during the Test and Disposal Phases, respectively. An estimated 1.3×10^{-7} and 3.1×10^{-7} excess fatal cancers per year are projected among the 113,000 population within 50 miles of the WIPP due to routine operations during the Test and Disposal Phases. The hypothetical maximally exposed individual is estimated to have 4.2×10^{-10} and 9.8×10^{-10} per year of contracting a fatal cancer during the respective Test and Disposal Phases.

Table 5.30 (for Alternative Action, see Table 5.55) shows health risks associated with maximum radiation exposures estimated for postulated accidents. An occupational worker would incur an estimated 17 in 10,000 (1.7×10^{-3}) excess risk of contracting a fatal cancer should the three-drum accident scenario occur in the waste handling building (Scenario C3 involving 100 PE-Ci drum). Health risk associated with the dose to a member of the public situated just beyond the secured area fence following the 1000 PE-Ci drum fire (Scenario C10), is about 4.8 in 10,000 (4.8×10^{-4}). An estimated 7.6×10^{-2} excess fatal cancers are projected among the 35,500 population within 50 miles of the WIPP in the westerly direction following Scenario C10. If the exhaust HEPA filtration system is automatically or manually activated, these risks drop by a factor of one million.

A beyond design basis accident (Scenario C8, hoist system failure) is discussed in Subsection 5.2.3.4 and in Appendix F.3. It is not discussed in this Subsection since it is not considered to be a reasonably foreseeable event.

Potential ecological consequences are based on the predicted off-site radionuclide concentrations in the air. Maximum annual average off-site air concentrations, assumed to be of Pu-239, are approximately 1×10^{-6} picocuries/m^3. This concentration will result in a soil contamination level of 6×10^{-4} picocuries/cm^2. The average level of plutonium in soils has been estimated at 0.14 picocuries/cm^2 (Eisenbud, 1987), which is attributable to fallout from atmospheric testing of nuclear weapons. The radiation exposures to the ecosystem by routine radiological releases are an order of magnitude less than radiological background levels.

Consequences of Waste Retrieval. Radiological exposures from routine and accidental releases during waste retrieval are estimated to be similar to or less than exposures during waste emplacement. The associated human health and ecological consequences would be in the same range.

Routine retrieval operations are anticipated to require more manpower and time than corresponding emplacement activities. The total occupational exposure over the retrieval period is expected to be greater than that of the approximate 5-year Test Phase, but the annual collective exposure to the worker population at the WIPP site is predicted to be slightly less. Routine off-site exposure to a hypothetical member of the public at the point of highest annual average air concentration at or beyond the WIPP-site boundary will be significantly less than that of waste emplacement operations

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during the Test Phase. This is primarily due to the intended use of enclosures containing on-line HEPA filtration in which retrieval operations are expected to occur.

The range of potential accidents during the retrieval process is expected to be similar to those postulated during emplacement and, therefore, should have similar, or smaller, on-site and off-site consequences to those projected for the operational phases of WIPP. The likelihood of some container failure accidents may be slightly higher during the retrieval process as a result of possible waste container degradation that may occur during the Test Phase and the complications associated with back-filled waste removal. However, HEPA filtered contamination control areas will be constructed around the active retrieval chamber to mitigate any accidental release of radioactive material and therefore calculated off-site consequences are expected to be considerably less than during the Test or Disposal Phase. Airflow in the control area would be maintained such that workers remain upstream of the working face of the waste stack. As such, potential worker exposure under retrieval accident conditions are anticipated to be similar to or less than that predicted for accidents during emplacement.

5.2.4 Risk Assessment and Analysis of Hazardous Chemical Environmental Consequences of Operations and Possible Retrieval of Waste at the WIPP

This subsection examines the potential environmental and human health impacts associated with the hazardous chemical components of TRU waste resulting from waste handling activities at the WIPP during the Test Phase and disposal operations. Impacts of hazardous components were not considered in the FEIS (SEIS Subsection 10.2). This risk assessment identifies viable migration pathways and estimates potential chemical releases via each relevant migration pathway. Potential pathways of human and environmental exposure are also identified and exposures are estimated based on relevant chemical release scenarios. Finally, the potential risks associated with the exposure estimates are provided. A description of the general risk assessment methodology is provided in Subsection 5.2.3.2.

Routine operations at the WIPP, aboveground and underground, are considered in the hazardous chemical risk assessment, consistent with the scope of the radiological risk assessment in the FEIS and in the SEIS, Subsection 5.2.3 and Appendix F. Potential accident scenarios and associated hazardous chemical releases are also considered. The initial approximate 5-year Test Phase in the Proposed Action includes bin- and room-scale tests, including a maximum of 10 percent receipt of waste.

An analysis of the uncertainties affecting the risk estimates is presented in Subsection 5.2.4.1. Subsection 5.2.4.2 describes the methodology used in the chemical risk assessment. Subsection 5.2.4.3 evaluates potential hazardous chemical release fractions and exposures that may be associated with routine operations. Subsection 5.2.4.4 addresses those potential risks resulting from a series of hypothetical accident scenarios. Subsection 5.2.4.5 identifies potential human health consequences associated with the estimates of chemical exposures.

5.2.4.1 Uncertainty Analysis. Human health risks posed by a defined set of circumstances may be evaluated both qualitatively and quantitatively. The accuracy

of these estimates is limited by the size and quality of the data base. In this assessment, these limitations have been mitigated by defining a range of extremes. However, there are varying degrees of uncertainty associated with estimating the risks that may result from chemical exposure. These uncertainties have been addressed throughout the risk assessment by making conservative assumptions where appropriate. Specific areas of uncertainty include:

- Exposed populations
- Waste characterization
- Air dispersion modeling
- Exposure estimates
- Toxicological data and risk characterization
- Complex interactions of uncertainty elements.

The uncertainty elements are reviewed here. Despite the conservative assumptions employed to counteract the uncertainties, the estimates of risk are best viewed in a qualitative sense (i.e., in relation to other potential risks, and not as absolutes).

Exposed Populations. To achieve the most precise estimates of potential risks (if any) to the community, populations representing varied exposure scenarios should be modeled. Recognizing this variability, exposed individual locations were selected to include a hypothetical residential exposed individual located at the maximum predicted concentration point at the site boundary, a hypothetical worker located at the maximum on-site concentration point, and a hypothetical worker located in an underground disposal chamber throughout his/her work shift.

In addition, the locations of potential maximum off-site ambient air concentrations of the representative chemicals were also subjected to air transport and exposure assessment modeling. The exposure scenario assumed that a hypothetical individual would be continually exposed to the highest potential WIPP site boundary concentration of each type of chemical constituent. However, no individual can be expected to remain in the same location 24 hours per day, 365 days per year for 25 years. Similarly, no job description requires a worker to remain at a single location throughout his/her working lifetime. Therefore, this scenario does not reflect realistic circumstances or any future projected exposure.

Waste Characterization. To derive a chemical-specific emissions data base, the limited data available on the potential future waste was evaluated. Assumptions regarding waste that is expected to be accepted at the WIPP are based on RCRA data for newly generated waste from the Rocky Flats Plant and waste from the Rocky Flats Plant that is currently in retrievable storage at the Idaho National Engineering Laboratory, process information, and a study of headspace gas concentrations (Clements and Kudera, 1985). From these data, a list of six representative chemicals was compiled. It must be stressed that although other constituents are expected to be present in the waste, quantitative analytical data do not exist for both waste composition and headspace gas concentration. The quality of the data suggests that it would be prudent to view the numerical results in a qualitative and, therefore, relative sense.

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Air Dispersion Modeling. Meteorological dispersion was estimated using the Industrial Source Complex (ISC) model in both short-term and long-term modes. Accuracy of the ISC model projections is generally recognized to be within a factor of two. For example, if the concentration calculated for a given receptor location is 100, then the actual concentration would be expected to fall in the range of 50 to 200 (i.e., 100/2 to 100 x 2).

For calculations of long-term concentrations of hazardous chemicals, a constant emission rate over an annual period is assumed. The concentrations at the exposed individual locations reported for short-term events were the highest of those estimated from the 49 combinations of wind speed and direction.

Exposure Elements. The exposure assessment utilized mathematical models that relied heavily on estimates of the ultimate disposition of the representative chemicals and their transport through inhalation. A review of the basis for mathematical models for exposure estimation is provided below. Model assumptions are reviewed below to illustrate the conservative bias built into the assumptions in order to compensate for uncertainty. Where reasonable approximations of the site-specific scenario could be estimated, default values that erred on the side of overestimation of exposure were utilized for input parameters such as building downwash. No field studies were performed. Existing data obtained from appropriate sources were employed.

Basis for the Mathematical Models of Exposure Assessment. Mathematical models, such as those employed in the exposure assessment, are helpful in providing numerical approximations of a biological system's response given a particular set of input conditions and constraints. The risk assessment models provide predictive estimates of the effects of chemicals in a given biological system. Here, the biological systems affected are the individual populations.

Any attempt to model a biological system incorporates some degree of uncertainty. For example, in modeling the transfer of a chemical across the alveoli in the lung, it is necessary to quantify penetration to the deep lung and the absorption rate across alveolar membranes. If these values do not exist as a result of previous scientific inquiry, assumptions are made that permit estimation from the most relevant information available. The precision of the resulting estimate of dose incurred depends on the accuracy of these assumptions reflecting actual events.

In essence, the scientist has taken a system in which many variables exist and constructed a manageable model of that system by assuming those variables are constant at a defined level. Under this approach, the input chemical concentration is the only independent variable in the model. A linear relationship between chemical concentration and intake is assumed that is not necessarily reflective of real-world conditions. The dependent variable (the intake) becomes a function of chemical concentration alone, which may not truly reflect site-specific conditions. This intake is qualified by the constraints on the model.

Assumptions Used in the Exposure Assessment. The assumptions used in the health-protective approach to defining the variables include the following:

- Continuous emissions from the WIPP (i.e., 24 hours a day, 365 days a year for the approximate 5-year Test Phase and the 20-year facility operating life)

- One hundred percent uptake and absorption of volatile organics

- Continuous maximum exposures for individuals (i.e., 24 hours a day, 365 days a year for 25 years)

- Continuous maximum exposures for each occupational worker for each shift.

Toxicological Data and Risk Characterization. The overriding uncertainties associated with the risk characterization are:

- The extrapolation of toxic or carcinogenic effects observed at the high doses necessary to conduct animal studies to effects that might occur at much lower, more realistic doses

- The extrapolation from toxic effects in animals to toxic effects in people (i.e., responses of animals may be different from responses of humans).

These extrapolations form the basis used to estimate risks. The carcinogenic potency factors (CPFs) are derived using a weight-of-evidence approach to studies in scientific literature (EPA, 1986). Due to the lack of human epidemiological data for most chemicals, the evidence is based on animal studies in which experimental groups were exposed for most of their lifetimes to doses many times those normally found in the environment. In some cases, only a single study may be used in this derivation process.

The EPA uses a prescribed protocol (EPA, 1986) in using animal data to estimate human cancer potency factors. The model utilized is the linearized multistage extrapolation model which provides a mathematical approximation of the dose-response slopes. Of the half dozen equally feasible dose-response extrapolation models available, the one selected by these agencies, as applied here, is designed to define the highest upper-bound risk condition. The results from this model likely overestimate the actual risk rather than underestimate it. The scientific evidence relating to the mechanism by which some of the chemicals in the database (e.g., chlorinated hydrocarbons) induce cancer in rodents leads to the conclusion that they may require additional biological alteration before initiating cancer. This renders those models invalid for applying to those chemicals. In addition, because the slope estimates are based on animal data, the ratio of cancer potency slopes between chemicals may be more reflective of animal responses than human. In short, because the models do not incorporate the role of biologic protective mechanisms or human epidemiology, they are only gross indicators that are specifically designed to overestimate potential risks.

Much valuable information has been gained from animal studies as a result. However, variations in pharmacokinetics and metabolism occur when identical experiments are carried out using different animal species. These species-to-species variations in responses exacerbate the difficult task of extrapolating from effects seen in animals to predicting effects in humans. In addition, the metabolic or pharmacokinetic

U. OF I. URBANA-CHAMPAIGN

idiosyncrasies of a given animal model may result in effects that may not occur in humans because humans may respond to a given chemical differently.

The high doses used in these animal studies also add additional levels of uncertainty. High dose levels may result in saturation effects in certain biochemical systems of an organism. For example, enzyme kinetics are vastly altered at substrate saturation levels. Effects seen at high doses may not represent the kinetics of the particular enzyme system under lower dose, nonsaturated conditions.

Even in cases where there are adequate epidemiological data, uncertainty persists. The exposures in such studies are not controlled in the sense of a laboratory experiment, and it is often impossible to isolate an exposure to a specific chemical. Therefore, the effect(s) observed may actually result from the interaction of a mixture of chemicals peculiar to that exposure incident. Unless the potential chemical mixture is fully defined, extrapolation to other exposure scenarios involves uncertainty.

Acceptable intakes for chronic exposure, threshold limit values and ceiling limits that have been established for noncarcinogens are derived in a similar manner. Hence, the same degree of uncertainty exists.

Complex Interaction of Uncertainty Elements. A risk assessment of a site is ultimately an integrated evaluation of historical, chemical, analytical, environmental, demographic, and toxicological data that are as site-specific as possible. To minimize the effect of uncertainties in the evaluation, each step is biased toward health-protective estimations. Since each step builds on the previous one, this biased approach more than compensates for risk assessment uncertainties. (These calculations do not represent currently existing or anticipated future exposures or health risks. Rather, they are estimations that occur only if all of the conservative assumptions are realized.)

5.2.4.2 Hazardous Chemical Risk Assessment Methodology. The estimation of human health risks characterizes the general range of potential risks based on a selected set of assumptions. The accuracy of such estimates is limited by the quantity and quality of available data. The waste-related chemical characterization data for this assessment are based on limited quantitative data on concentrations of chemicals in the TRU mixed waste. The estimates resulting from this limited database, such as the one relied on in this report, should be considered relative and not absolute. In this assessment, uncertainties that may result from insufficient analytical data available on waste chemistry are mitigated by employing a series of conservative assumptions that yield ranges of extremes. This approach to managing uncertainties tends to overestimate risks rather than underestimate them.

The assumptions in the risk assessment result in a strong bias toward health protection. For example, in estimating occupational exposures from routine operations for the approximate 5-year Test Phase and the 20-year operational period, workers were assumed to spend an 8-hour shift every work day at the points above- and below-ground identified as the locations of the highest chemical concentrations. As another example, a hypothetical exposed individual was placed at the site boundary at a point of maximum potential exposure and was assumed to be present at that

location continuously for 20 years. The effects associated with such highly improbable conditions should be greater than the effects associated with more realistic scenarios.

Migration Pathways. The media through which hazardous chemicals may travel to reach individuals include air, ground and surface waters, and soil. Subsection 5.2.3 of this SEIS examines the viability of each pathway for radionuclide releases and explains why, of these, air is the only credible pathway. Because of the physical forms of the hazardous chemicals in the waste, operational protocols, and the nature of the repository, the potential pathways for hazardous chemical releases are the same as those for radionuclide releases.

Evaluation of Waste-Related Chemical Data. CH TRU waste from the Rocky Flats Plant, currently in retrievable storage at the Idaho National Engineering Laboratory, and newly generated waste from the Rocky Flats Plant will contribute about 86 percent by volume of the total inventory of TRU mixed waste to be emplaced in the WIPP (WEC, 1989). For analysis purposes, it was assumed that all of this waste contains the estimated maximum concentrations of hazardous chemicals present in newly generated CH TRU waste from the Rocky Flats Plant (Table 5.31). As described in Subsection 3.1.1.2, these estimates are based on knowledge of the waste or waste generating processes.

Past practices at the Rocky Flats Plant indicated that 1,1,1-trichloroethane was substituted for trichloroethylene in about 1975. Trichloroethylene was detected in the headspace gas of drums sampled at the Idaho National Engineering Laboratory (Clements and Kudera, 1985), therefore, it was assumed to have the same total concentration in the waste as 1,1,1-trichloroethane and was included in the risk assessment. Based on the above considerations and the data limitations, five volatile organic compounds and one metal were selected as representative of the chemical waste likely to be stored at the WIPP. Each is predicted to average greater than one percent of the waste by weight. The representative chemicals are:

- Carbon tetrachloride
- Methylene chloride
- 1,1,1-trichloroethane
- 1,1,2-trichloro-1,2,2-trifluoroethane (Freon 113)
- Trichloroethylene
- Lead.

Trichloroethylene, carbon tetrachloride and methylene chloride are considered to be potential human carcinogens, while 1,1,1-trichloroethane and Freon 113 are known to produce adverse somatic effects when present in sufficient concentrations. Appendix G provides a more detailed discussion of the toxic properties of these chemicals.

Analytical data were not available on the concentrations of metals in TRU waste. However, information provided by DOE generator sites for preparation of the Part A permit application under RCRA indicates that lead is the most prevalent RCRA-regulated, hazardous metal by both weight and volume (WEC, 1989). Other metals which may be present in TRU mixed waste, based on process knowledge and/or knowledge of the waste, are included in Table 5.32.

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TABLE 5.31 Estimated concentrations of hazardous constituents in TRU mixed waste from the Rocky Flats Plant [a]

Hazardous constituent	Minimum	Maximum
	mg/kg	
1,1,1-trichloroethane	15	150,000
Trichloroethylene[b]	15	150,000
Carbon tetrachloride	25	50,000
1,1,2-trichloro-1,2,2-trifluoroethane	75	50,000
Methylene chloride	50	750
Methyl alcohol	0	25
Xylene	0	50
Butyl alcohol	0	10
Cadmium	0	10
Lead	0	1×10^6

[a] Rockwell International, 1988.

[b] No estimates were available on the total concentration of trichloroethylene. Based on knowledge of past industry practice, the concentration was assumed to be equivalent to that of 1,1,1-trichloroethane.

Particulate releases of heavy metals during routine operations are assumed to be insignificant due to:

- The strict WAC certification requirements and operational procedures to assure that limited radioactive contamination exists on the surfaces of containers (e.g., 50 pCi/100 cm^2 for alpha emitters and 450 pCi/100 cm^2 for beta and gamma emitters). Assuming an average inventory of radionuclides, the maximum mass concentration of surface contaminants on CH TRU drums is equal to 1.3×10^{-10} g/100 cm^2. This concentration is orders of magnitude below detectable levels for RCRA-regulated metals.

- The nature of the metal containing waste. Metal in the waste, most of which is lead in monolithic forms, is present in bricks and shielding rather than in particulate form (WEC, 1989). The primary sources of other metals are in the forms of sheets, rods, or parts of equipment.

TABLE 5.32 Hazardous chemical constituents reported in CH TRU mixed waste for which no estimates on concentrations are available[a]

Metals[b]	Organics[b]
Arsenic	Tetrachloroethylene
Barium	Acetone
Chromium	
Mercury	
Selenium	
Silver	
Beryllium	

[a] Information obtained from the "Radioactive Mixed Waste Compliance Manual," (WEC, 1989).

[b] Based on knowledge of the waste and/or the processes that generate it.

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For certain hypothetical accident events, particulate release of lead, the representative metal, was evaluated. Because of the types of hazardous chemicals and the physical waste forms associated with the chemical components of RH TRU mixed waste, no releases of hazardous chemicals during routine operations or accidents were postulated. RH TRU mixed waste does not contain RCRA-regulated volatile organic compounds (WEC, 1989), and, similar to CH TRU mixed waste, lead is its most prevalent metal, occurring primarily as shielding. RH TRU process waste (i.e., sludges) will be solidified (e.g., vitrified or cemented) prior to shipment to the WIPP. Therefore, routine releases of hazardous chemicals from RH TRU mixed waste were not considered to be realistic events. The only accident considered in the draft FSAR for RH TRU waste was the release of radioactive particulates from a canister that was dropped from the hot cell into the transfer cell. Hazardous chemicals are not expected to be associated with a particulate fraction in RH TRU waste.

Estimate of Release Fractions. In addition, the estimated concentrations of chemicals in the waste must be estimated to determine the quantity of each chemical potentially available for release to the environment. Chemical, biological, and radiological processes that occur in the waste are also important since they influence the types of chemicals released and their release rate.

Volatilization and degradation of organic compounds are the two primary processes that produce gases in drums of TRU waste. The volatilization of organic constituents in mixed waste is a function of their vapor pressure in relation to the ambient temperature of the matrix in which they occur. Radiolytic and microbial degradation of TRU waste generate primarily hydrogen, carbon dioxide, and oxygen. The concentration of all gases in any particular drum of waste is a function of the various processes occurring at a given time.

Studies on gas generation rates conducted at the Idaho National Engineering Laboratory (Clements and Kudera,1985) provide the basis for estimating concentrations of selected volatile organics in the waste drums during the Test Phase and disposal operations at the WIPP, and for postulating release fractions. The studies were conducted as part of a TRU Waste Sampling Program conducted at the Idaho National Engineering Laboratory to evaluate various types of TRU waste received from the Rocky Flats Plant for storage. A total of 13 waste forms (combustibles, sludges, metals, etc.) was randomly selected (out of the waste forms expected to comply with the requirements of the WIPP WAC) to verify the effectiveness of certification procedures. The nature and objectives of the study necessitated that the drums have airtight seals to allow accurate measurement of gas generation rates, gas concentrations, and void volumes. Under these conditions, the headspace gases of 172 drums were sampled and analyzed.

The "void volume" is the total volume of a drum occupied by gases. The average void volume was used to calculate the total grams of a volatile organic compound in the gas phase of each drum. The average void volume within the drums sampled was calculated to be 147 L. Since 55 gals is equal to approximately 208 L, it is assumed that more than half of each drum is comprised of air and other gases.

The average concentrations of the selected volatile organic compounds in the headspace of the drums are given in Table 5.33. Although it was assumed that this concentration of gases is present in every drum, analytical results from Clements and Kudera (1985) indicate the volatile organic compounds are often below detection limits (Table 5.34). Therefore, the assumption that every container of waste has an average concentration of volatile organic compounds in the headspace provides a representative estimate of potential emissions.

It should be noted that headspace gas concentrations cannot be directly correlated to the total concentrations in the waste because of the complex chemistry of the vapor-waste equilibria distribution of the organic compounds. For example, in waste forms containing bound water (i.e., solidified sludges), the vapor pressure of the organics is reduced appreciably. The volatile organic compounds present in the waste include those that exert appreciable vapor pressures at ambient temperatures expected in the WIPP (e.g., Freon 113 and methylene chloride). Generally, the vapor pressure of a pure compound is not completely exerted when the compound is in a combined form with other substances. For example, waste was vented through carbon composite filters for 13 weeks and then purged and sealed (Clements and Kudera, 1985). They observed a decrease in the concentrations of volatile organics in the headspace of drums containing combustibles, indicating that the source term of the organics was limited. The data from Clements and Kudera (1985) represent the concentrations of volatile organic compounds that potentially may be released to the air while the waste is being managed.

Waste containers for shipment to the WIPP will be vented through a carbon composite filter to prevent pressurization of the drums due to hydrogen gas generation during transportation. To evaluate risks associated with the chemical components of the waste during the Test Phase and throughout 20 years of disposal operations, a release rate of gas from each drum through the filter was derived from data obtained through experiments conducted by Westinghouse Electric Corporation (WEC, 1988b). The release rates (Table 5.35) were estimated by relating the diffusion rate of hydrogen to these volatile organic compounds. The diffusion coefficients of the volatile organics were computed by multiplying the hydrogen diffusion coefficient by the square root of the ratio of hydrogen to the specific gas molecular weight. No credit was taken for any adsorption of the organics on the carbon composite filters. It was also assumed that the volatile organic compounds were emitted at a constant rate. In reality, the emission rate of volatile organic compounds will decrease over time as their concentrations in the waste container decrease.

Potential Releases of Hazardous Chemicals. Potential releases to air during the Test Phase and Disposal Phase operations belowground were modeled for the 5-year and 20-year period, respectively, based on the amount of waste projected to be emplaced in the facility during these times. Each underground disposal room has a capacity of approximately 6,000 55-gal drums. The analysis assumes that during the Test Phase, the WIPP would accept up to 88,000 drum-equivalents. This represents about 10 percent of the 6.2 million cubic ft of total repository capacity for CH TRU waste.

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TABLE 5.33 Average concentrations of selected volatile organic compounds in the headspace of TRU waste drums[a]

Hydrocarbon	Average concentration (g/L)[b]
Carbon tetrachloride	1.9×10^{-3}
Methylene chloride	0.5×10^{-3}
Trichloroethylene	7.0×10^{-4}
1,1,1-trichloroethane	13.2×10^{-3}
1,1,2-trichloro-1,2,2-trifluoroethane	1.2×10^{-3}

[a] Clements and Kudera, 1985.

[b] g/L: grams per liter

TABLE 5.34 Number of drums containing detectable quantities of selected organics in TRU waste from the Rocky Flats Plant[a]

Volatile organic compound[b]	Number of drums containing detectable quantities	Percentage of drums containing detectable quantities[c]
Carbon tetrachloride	12	7
Methylene chloride	21	12
Trichloroethylene	29	17
1,1,1-trichloroethane	91	53
Freon-113	11	6

[a] Clements and Kudera, 1985.

[b] Volatile organic compounds were selected based on available estimates of their total concentrations in waste from the Rocky Flats Plant (Rockwell, 1988).

[c] Percentages based on a total of 172 drums sampled.

Because this is the Test Phase for the facility, the disposal rooms would not be backfilled. Therefore, the period of maximum potential exposure is assumed to be during the Test Phase because none of the rooms would be backfilled during this period. If the decision were made after the Test Phase to continue the project into the Disposal Phase, these rooms would then be backfilled. In the Disposal Phase, it is assumed that the facility would receive an average of 39,600 drum-equivalents of CH TRU waste per year.

Aboveground operations that may lead to potential releases are expected to occur in the waste handling building (WHB). It is here that TRUPACT-IIs would be opened and the individual drums readied for emplacement in the underground disposal rooms. Three TRUPACT-IIs (i.e., 42 drum-equivalents) were assumed to be present at all times in the WHB.

Releases of small quantities of volatile organic compounds to the air are expected to occur during waste receipt, handling, and emplacement activities. Releases of volatile organic compounds from TRU waste containers into the TRUPACT-II during transport may occur. Before opening the TRUPACT-II, gas samples would be taken from the sample port to detect any accumulation of volatile hazardous chemicals. If hazardous chemicals are present, the TRUPACT-II would be opened under a negative air flow or purged, and hazardous VOCs would be removed by a charcoal filter system prior to release from the WHB. After receipt, individual drums being readied for emplacement in the underground disposal chambers may be held in the WHB for a period of hours. Routine releases in the WHB are expected to be negligible, since diffusion rates of VOCs through filters are very low.

The following assumptions were used to estimate potential releases of hazardous chemicals to air in the WHB and the underground disposal area:

- Emissions from the waste drums occur at a constant and continuous rate until the available source is depleted.
- During the Test Phase, waste drums accumulate underground at the facility at the rate of 17,600 drums per year.
- During the Test Phase, individual underground disposal rooms are filled on the first day of each year (i.e., on day one of year one, 17,600 drums arrive and begin the emission pattern described above; on day one of year two, another 17,600 drums arrive, etc.). At the beginning of the fifth year, the full complement of 88,000 drums is in storage.
- After the Test Phase, no more than 6,000 drums (i.e., one full room) would be available as an underground emission source at a given time.
- No more than 3 TRUPACT-IIs (a total of 42 drums) would be opened in the WHB at any one time. Therefore, the maximum emission source aboveground is a 42-drum unit. It was assumed that three TRUPACT-IIs would always be open in the WHB.

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TABLE 5.35 Average emission rates of selected volatile organic compounds through the carbon composite filters of TRU waste drums

Hydrocarbon	Average emission rate (g/s)[a]
Carbon tetrachloride	2.3×10^{-8}
Methylene chloride	7.8×10^{-9}
Trichloroethylene	9.3×10^{-9}
1,1,1-trichloroethane	1.7×10^{-7}
1,1,2-trichloro-1,2,2-trifluoroethane	1.4×10^{-8}

[a] g/s: grams per second

- Releases consist of vaporized organic solvents. The drums are sealed and vented through carbon filters. During Disposal Phase operations the integrity of the drums and their filters is maintained and, therefore, no particulates are available for release.

Table 5.36 gives the total emission periods used for each compound. As shown, 3 compounds would not be emitted for the entire 5-year Test Phase (approximate) if the minimum reported concentration was present.

Air Dispersion Modeling. As with radioactive waste contaminants, airborne release of hazardous chemicals from the WHB and the underground disposal area constitute the most important potential exposure pathway. The maximum possible exposures from inhalation of airborne releases of hazardous chemicals were estimated for workers at the WIPP and the public (i.e., maximally exposed individual). Consistent with radiological dose assessments (DOE, 1988c), the maximally exposed member of the public is placed at the site boundary which is the point of maximum potential exposure.

The EPA Industrial Source Complex (ISC) Dispersion Model predicts off-site concentrations of volatile organic gaseous releases from the WHB and underground disposal areas. The same stack parameters (i.e., height, exhaust velocity, and diameter) were used in this model as in the AIRDOS-EPA radiological dispersion model (Appendix F). The long-term version of the model was used for routine operations, while the short-term version was used to predict off-site concentrations of chemicals during accident scenarios. A detailed description of these models and the input parameters is provided in Appendix G.

TABLE 5.36 Estimated emission periods for volatile organics based on total concentrations and emission rates through the container filter

Chemical	Emission Period (Years)[a] Minimum	Maximum
Carbon tetrachloride	4	8,345
Methylene chloride	3	37
Trichloroethylene	31	61,111
1,1,1-trichloroethane	2	3,280
1,1,2-trichloro-1,2,2-trifluoroethane	21	14,093

[a] The estimated total concentrations of each organic from Table 5.31 is multiplied by the emission rate given in Table 5.35 to determine the number of years that potential releases may occur, assuming that the gases flow at a constant rate through the carbon composite filter. An average drum weighs 120 kg (265 lbs) (WEC, 1989).

The concentrations of constituents in environmental media are not considered to be static levels. Changes in the concentration of the waste being emplaced; potential environmental transport mechanisms, such as wind; and potential relocation of exposed individuals create variable conditions which directly impact the air concentration over time to which an individual may be exposed. In order to represent a more realistic exposure concentration, the concept of an average concentration is used in the approximate 5-year Test Phase for underground and aboveground operations. Therefore, the modeled concentration in air was modified by a weighting factor to account for the additive effect of drum-units being emplaced each year. It was assumed that all containers of waste contain the maximum total concentration of volatile organic compounds estimated for Rocky Flats Plant waste (Table 5.31). If waste contains less than maximum concentrations of volatile organics, the organic constituents would not be emitted during the entire Test Phase based on the estimated emission periods of the volatile organic compounds in the waste (Table 5.36). These emission periods are shown in Table 5.36. The calculation of the weighting factor, however, includes the conservative assumption that the compounds will be emitted for the entire Test Phase period. This adds a level of conservatism to the estimation of the concentration in air to which the receptors may be exposed.

Risk Assessment and Characterization. The estimation of human health risks associated with potential exposures to hazardous chemicals is based, to the extent appropriate, on

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the guidance provided by the Superfund Public Health Evaluation Manual (SPHEM) (EPA, 1986). Consistent with the conservative approach, potential exposures to releases of hazardous chemicals resulting from Disposal Phase operations were estimated for hypothetical workers located at the points of maximum on-site concentrations above- and belowground identified by the air dispersion modeling. Estimates of potential exposures were also made for a hypothetical resident placed at the site boundary at a point of maximum potential exposure. The modeling results were used to assess air pathway exposures for these residential and occupational individuals. Short-term exposures were also evaluated for appropriate accidental release scenarios. A detailed description of the exposure parameters and calculations of risk estimations is given in Appendix G.

Exposure Periods for Routine Operations. It was assumed that the residential exposure period is 24 hours per day, 365 days per year. This is a conservative assumption. The occupational exposure scenario was based on an 8-hour work day and a 5-day work week. The working year was considered to be 240 days, allowing about 20 days per year for vacation, holidays, and sick leave.

Exposure Periods for Accident Events. Accident scenarios were evaluated as short-term events. Times of occupational exposure were assumed for each scenario and exposure estimates were based on these times. For aboveground accident events, it was assumed that a vapor cloud resulting from the accidental release would take one minute to pass the occupational worker location. For underground accidents, a 15-second period was assumed for the vapor cloud to pass. These exposure periods are calculated based on air flow in the WHB and underground, respectively. No particulate release is expected during these periods due to the nature of the waste form (Appendix B). No data were available to estimate the probable duration of an underground fire in a single drum. A release period of 30 minutes was assumed for this hypothetical accident scenario.

Hazardous Chemical Risk Evaluation for Waste Retrieval. Risk evaluation for waste retrieval was calculated in the same way as for emplacement. Containers were assumed to maintain their integrity during the Test Phase and throughout the retrieval period. The intake of hazardous chemicals by the maximally exposed individual during the retrieval period was estimated assuming a 10-year exposure period.

5.2.4.3 Routine Releases and Exposures for Hazardous Chemicals. Routine releases of hazardous chemical constituents in the TRU waste are quantified in this subsection. Exposures to workers and the hypothetical, maximally-exposed member of the public who resides at the WIPP site boundary are discussed, and possible health consequences are evaluated. Releases and exposures are predicted for WIPP operations and waste retrieval.

Occupational Exposures from Aboveground Operations. Releases to the air are expected to occur during waste receipt, handling, and emplacement activities. Releases from TRU waste containers into the TRUPACT-II during transport may occur. Before opening the TRUPACT-II, samples will be taken from the sample port to detect any accumulation of hazardous chemicals. If hazardous chemicals are present, the TRUPACT-II will be opened under a negative air flow or purged, and hazardous volatile

organic compounds will be removed by a charcoal filter system prior to release from the WHB. After receipt, individual drums being readied for emplacement in the underground disposal chambers may be held in the WHB for a period of hours. Routine releases in the WHB are negligible because diffusion rates of volatile organic compounds through filters are very low.

Consistent with the conservative approach for this assessment, a hypothetical worker was placed at the maximum concentration point for the aboveground operations as predicted by the air dispersion modeling of the waste handling activities. Potential exposures to workers from aboveground operations are postulated by assuming the presence of 42 drums (one TRUPACT-II truckload) in the WHB at all times. Therefore, the estimated air concentrations and the daily intakes are the same for the Test Phase and the operational period. The maximum concentration point from aboveground operations was 500 m (1,640 ft) south and 200 m (656 ft) west of the ventilation exhaust for the WHB, the assumed release point.

Table 5.37 gives the estimated concentrations in air of hazardous chemicals for the aboveground occupational exposed individual location. These concentrations range from 2.0×10^{-7} $\mu g/m^3$ for methylene chloride to 4.5×10^{-6} $\mu g/m^3$ for 1,1,1-trichloroethane. Table 5.37 also includes the estimated daily intakes for each

TABLE 5.37 Occupational exposures and estimated daily intakes during aboveground operations

Chemical	Concentration at receptor[b] ($\mu g/m^3$)	Maximum estimated daily intake[a] (mg/kg/day)	
		5 years	20 years
Carbon tetrachloride	5.9×10^{-7}	1.0×10^{-10}	1.0×10^{-10}
Methylene chloride	2.0×10^{-7}	3.4×10^{-11}	3.4×10^{-11}
Trichloroethylene	2.4×10^{-7}	4.1×10^{-11}	4.1×10^{-11}
1,1,1-trichloroethane	4.5×10^{-6}	7.7×10^{-10}	7.7×10^{-10}
1,1,2-trichloro-1,2,2-trifluoroethane	3.5×10^{-7}	6.0×10^{-11}	6.0×10^{-11}

[a] Estimated daily intake (mg/kg/day) = [receptor concentration ($\mu g/m^3$)] $\frac{[1\ mg]}{[1000\ \mu g]}$ [respiratory volume (m^3/day)]/[body weight].
The respiratory volume is 12 m^3/day and the body weight is 70 kg.

[b] Because it is conservatively assumed that 42-drum units are present in the WHB at all times, the air

chemical for the aboveground worker. The range of intakes is bounded by a low of 3.4 x 10^{-11} mg/kg/day for methylene chloride and a high of 7.7 x 10^{-10} mg/kg/day for 1,1,1-trichloroethane.

Occupational Exposures from Underground Operations. Potential exposures to workers from underground operations may result from the off-gassing from drums placed in the underground disposal rooms. To provide estimates of these potential exposures, hypothetical workers were placed:

- Underground in a disposal chamber for an entire eight-hour shift each work day. This worker was assumed to be exposed to the emissions of a 6,000-drum unit. The exposure was based on a room volume of 3,600 m^3 (127,116 ft^3) and on air velocity of 0.4 m/sec (1.3 ft/sec).

- Aboveground at the maximum on-site concentration point as predicted by the air dispersion modeling of the underground releases. This point for releases from underground operations is located 300 m (984 ft) south and 100 m (328 ft) west of the release point. This worker was also assumed to remain at that location for the duration of the eight-hour shift.

These exposure models are conservative since airflow in the waste chambers will place workers upstream of the waste disposal room (DOE, 1988a). Table 5.38 gives the estimated concentrations of hazardous chemicals in the air for both worker locations. These concentrations are based on the specific "drum units" for each scenario. Since 6,000 is the maximum number of drums in a room that an underground worker may be exposed to, the exposures are equal for both 5-and 20-year periods. However, an aboveground worker may be exposed to a total of 88,000 drums during the Test Phase because no rooms will be backfilled during this time. The concentrations in the underground disposal room range from 2.9 $\mu g/m^3$ for methylene chloride to 8.5 $\mu g/m^3$ for carbon tetrachloride. At the aboveground receptor location, concentrations during the 5-year period range from 6.4 x 10^{-4} $\mu g/m^3$ for methylene chloride to 1.4 x 10^{-2} $\mu g/m^3$ for 1,1,1-trichloroethane. During the 20-year period, concentrations at the aboveground receptor location range from 7.2 x 10^{-5} $\mu g/m^3$ for methylene chloride to 1.6 x 10^{-3} $\mu g/m^3$ for 1,1,1-trichloroethane.

The estimated daily intakes for each chemical for both receptor locations are included in Table 5.39. Estimates of daily intake for the underground receptor range from 4.9 x 10^{-4} mg/kg-day for methylene chloride to 1.1 x 10^{-2} mg/kg-day for 1,1,1-trichloroethane. The range of intakes for the aboveground worker during the 5-year period is 1.1 x 10^{-7} mg/kg-day for methylene chloride to 2.5 x 10^{-6} mg/kg-day for 1,1,1-trichloroethane. During the 20 years of operations, the intakes for the aboveground worker are approximately an order of magnitude lower than intakes for aboveground workers during the Test Phase for each chemical constituent.

Residential Exposures from Aboveground Operations. Potential exposures to residential populations in the vicinity of the WIPP site may occur as a result of releases from the WHB during routine operations. Estimates of these potential exposures were calculated based on predicted maximum ground-level concentrations at the site boundary.

TABLE 5.38 Occupational exposures from underground operations

Chemical	Maximum concentration at receptor location: Underground worker[a] ($\mu g/m^3$) 5-yr	Underground worker[a] ($\mu g/m^3$) 20-yr	Aboveground worker[b] ($\mu g/m^3$) 5-yr	Aboveground worker[b] ($\mu g/m^3$) 20-yr
Carbon tetrachloride	8.5	8.5	1.9×10^{-3}	2.1×10^{-4}
Methylene chloride	2.9	2.9	6.4×10^{-4}	7.2×10^{-5}
Trichloroethylene	3.5	3.5	7.7×10^{-4}	8.7×10^{-5}
1,1,1-trichloroethane	6.5	6.5	1.4×10^{-2}	1.6×10^{-3}
1,1,2-trichloro-1,2,2-trifluoroethane	5.0	5.0	1.1×10^{-3}	1.3×10^{-4}

[a] The underground worker was assumed to be exposed to 6,000 drum-equivalents throughout the exposure period. Therefore, the air concentration remains constant.

[b] During the first 5-year period, the concentration of chemicals is multiplied by a weighting factor of 3 to represent the average concentration over that time. The weighting factor is explained in Appendix G. During the Disposal Phase, the concentration of chemicals is calculated based on a continuous emission of 6,000 drum-equivalents.

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TABLE 5.39 Routine maximum estimated daily intakes for underground operations

Chemical	Estimated daily intakes at receptor location[a] (mg/kg/day) 5-yr	20-yr
Underground worker[b]		
Carbon tetrachloride	1.5×10^{-3}	1.5×10^{-3}
Methylene chloride	4.9×10^{-4}	4.9×10^{-4}
Trichloroethylene	5.9×10^{-4}	5.9×10^{-4}
1,1,1-trichloroethane	1.1×10^{-2}	1.1×10^{-2}
1,1,2-trichloro-1,2,2-trifluoroethane	8.6×10^{-4}	8.6×10^{-4}
Aboveground worker[c]		
Carbon tetrachloride	3.2×10^{-7}	3.6×10^{-8}
Methylene chloride	1.1×10^{-7}	1.2×10^{-8}
Trichloroethylene	1.3×10^{-7}	1.5×10^{-8}
1,1,1-trichloroethane	2.5×10^{-6}	2.8×10^{-7}
1,1,2-trichloro-1,2,2-Trifluoroethane	1.9×10^{-7}	2.2×10^{-8}

[a] Estimated daily intake (mg/kg/day) = [receptor concentration ($\mu g/m^3$)] $\frac{[1\ mg]}{[1000\ \mu g]}$ [respiratory volume (m^3/day)]/[body weight].
The respiratory volume is 12 m^3/day and the body weight is 70 kg.

[b] The underground worker is exposed to 6,000-drum units (one full room) throughout the exposure period, therefore, the air concentration remains constant.

[c] The aboveground worker is exposed to an average of 52,800 drum-equivalents during the first 5 years and 6,000 drum-equivalents over the subsequent 20 years.

Table 5.40 gives the estimated concentrations in air of hazardous chemicals resulting from aboveground operations for a hypothetical resident located at the site boundary. These concentrations range from 4.1×10^{-8} $\mu g/m^3$ for methylene chloride to 9.3×10^{-7} $\mu g/m^3$ for 1,1,1-trichloroethane. Table 5.40 also includes the estimated daily intakes for each chemical for this receptor location. The range of intakes is 1.2×10^{-11} mg/kg-day for methylene chloride to 2.7×10^{-10} mg/kg-day for 1,1,1-trichloroethane. Again, no differences in exposure exist between the Test Phase and the 20-year Disposal Phase because the source term is a constant 42 drums in the WHB.

Residential Exposures from Underground Operations. Potential exposures to nearby residential populations may also occur as a result of releases from underground waste disposal during routine operations. Estimates of these potential exposures are calculated based on predicted maximum ground-level concentrations at the site boundary.

Table 5.41 gives the estimated concentrations in air of hazardous chemicals resulting from underground operations for the hypothetical exposed individual located at the site boundary. Concentrations during the Test Phase ranged from 7.1×10^{-5} $\mu g/m^3$ for methylene chloride to 1.6×10^{-3} $\mu g/m^3$ for 1,1,1-trichloroethane. The air concentrations during the Disposal Phase are somewhat lower, with a range from 8.1×10^{-6} for methylene chloride to 1.8×10^{-4} for 1,1,1-trichloroethane. The estimated daily intakes for each chemical for the hypothetical exposed individual are also included in Table 5.41. The range of intakes during the Test Phase is 2.0×10^{-8} mg/kg-day for methylene chloride to 4.5×10^{-7} mg/kg-day for 1,1,1-trichloroethane. The off-site exposures to hazardous chemicals during the Disposal Phase would be approximately an order of magnitude lower than those during the Test Phase if the decision is made to backfill. (It is assumed that backfilling would significantly reduce releases to the atmosphere.)

Waste Retrieval Releases and Exposures. If retrieval should become necessary, air samples would be taken in waste storage areas prior to entry to confirm that air concentrations of hazardous chemicals are within health-based limits. Appropriate respiratory protection would be worn if needed.

The routine releases of hazardous chemicals during waste retrieval are expected to be similar to releases during emplacement. The integrity of the waste containers is not assumed to deform or degrade during the retrievable storage period because the WAC requires that waste containers meet all requirements of 49 CFR 173.412 for Type A packaging, including a design life of at least 20 years.

Exposures to hazardous chemicals during routine retrieval operations were predicated on the assumptions established for routine waste emplacement. Workers involved with retrieval activities were assumed to be subject to the same exposure scenarios as those involved in underground emplacement activities during the first few years of facility operations. Because of the conservative assumption used to estimate worker exposures (i.e., a worker remains continuously in a room, exposed to 6,000 drum-equivalents), no greater exposure is expected during retrieval operations. The estimated daily intakes of hazardous chemicals by the maximally exposed member of the public would be no greater than that estimated for the first five years of underground emplacement activities. If retrieval activities were to be carried out, it is expected they would require a longer period than emplacement.

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TABLE 5.40 Residential exposures and estimated daily intakes during aboveground operations

Chemical	Concentration at the hypothetical individual receptor[b] ($\mu g/m^3$)	Maximum estimated daily intake[a] (mg/kg/day)	
		5-yr	20-yr
Carbon tetrachloride	1.2×10^{-7}	3.5×10^{-11}	3.5×10^{-11}
Methylene chloride	4.1×10^{-8}	1.2×10^{-11}	1.2×10^{-11}
Trichloroethylene	5.0×10^{-8}	1.4×10^{-11}	1.4×10^{-11}
1,1,1-trichloroethane	9.3×10^{-7}	2.7×10^{-10}	2.7×10^{-10}
1,1,2-trichloro-1,2,2-trifluoroethane	7.2×10^{-8}	2.1×10^{-11}	2.1×10^{-11}

[a] Estimated daily intake (mg/kg/day) = [receptor concentration ($\mu g/m^3$)] $\frac{[1\ mg]}{[1000\ \mu g]}$ [respiratory volume (m^3/day)]/[body weight].
The respiratory volume is 20 m^3/day and the body weight is 70 kg.

[b] Hypothetical individual is located at the point of maximum air concentration at the WIPP site boundary. The minimum and maximum air concentrations at the hypothetical receptor are the same for the 5-and-20-year scenarios. Forty-two drums are postulated to be in the WHB at all times, creating a constant concentration in air for the periods evaluated.

TABLE 5.41 Residential exposures and estimated daily intakes during underground operations

	Concentration at the hypothetical resident[a] ($\mu g/m^3$)		Maximum estimated daily intake[b] (mg/kg/day)	
	5-yr	20-yr	5-yr	20-yr
Carbon tetrachloride	2.1×10^{-4}	2.4×10^{-5}	6.0×10^{-8}	6.8×10^{-9}
Methylene chloride	7.1×10^{-5}	8.1×10^{-6}	2.0×10^{-8}	2.3×10^{-9}
Trichloroethylene	8.5×10^{-5}	9.7×10^{-6}	2.4×10^{-8}	2.8×10^{-9}
1,1,1-trichloroethane	1.6×10^{-3}	1.8×10^{-4}	4.5×10^{-7}	5.2×10^{-8}
1,1,2-trichloro-1,2,2-trifluoroethane	1.2×10^{-4}	1.4×10^{-5}	3.5×10^{-8}	4.0×10^{-9}

[a] The 5-year maximum air concentrations are multiplied by a weighting factor of 3 to represent the average concentration in air over time (Appendix G). The residential receptor is exposed to a constant 6,000 drum-equivalents during the 20-year Disposal Phase.

[b] Estimated daily intake (mg/kg/day) = [receptor concentration ($\mu g/m^3$)] $\frac{[1\ mg]}{[1{,}000\ \mu g]}$ [respiratory volume(m^3/day)]/[body weight]; where the respiratory volume is 20 m^3/day and the body weight is 70 kg.

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5.2.4.4 Accidental Releases and Exposures for Hazardous Chemicals. The accident scenarios for hazardous chemical releases and exposures are identical to those described for accidental radiological releases in Appendix F. They are identified by the same letter codes.

In modeling releases of chemicals, it was assumed that the total release of volatile organic compounds equals the calculated gas concentration in the void volume of the container for a given chemical (Subsection 5.2.4.2). Releases and potential acute exposures were estimated for occupational exposed individual in the immediate vicinity of the accident. Table 5.42 includes the estimated release fractions and potential exposures to these chemicals.

Occupational Exposures from Aboveground Accidents. There are two hypothetical accident scenarios that are applicable to aboveground operations. These accidents are postulated to occur in the WHB.

Accident ID C2. A single drum is dropped from a forklift. Concentrations of hazardous chemicals at a worker 20 feet away range from 1.5×10^{-1} mg/m^3 for methylene chloride to 4.1 mg/m^3 for 1,1,1-trichloroethane. The estimated intake range resulting from a one-minute exposure is 3.7×10^{-3} mg for methylene chloride to 1.0×10^{-1} mg for 1,1,1-trichloroethane.

Accident ID C3. Two drums are punctured by a forklift. A third drum falls and ruptures as a result of the initial accident. Concentrations at a worker 20 feet away range from 4.4×10^{-1} mg/m^3 for methylene chloride to 1.2×10^{1} mg/m^3 for 1,1,1-trichloroethane. The estimated intake range resulting from a one-minute exposure is 1.1×10^{-2} mg for methylene chloride to 3.1×10^{-1} mg for 1,1,1-trichloroethane.

Occupational Exposures from Underground Accidents. There are four hypothetical accident scenarios that are applicable to underground operations. These accidents were postulated to occur in underground disposal areas.

Accident ID C4. A transporter hits a pallet of drums in the underground disposal area. As a result, the lid is knocked off of one drum. Concentrations at a worker in the vicinity range from 8.3×10^{-1} mg/m^3 for methylene chloride to 2.3×10^{1} mg/m^3 for 1,1,1-trichloroethane. The estimated intake range resulting from a 15-second exposure is 5.2×10^{-3} mg for methylene chloride to 1.5×10^{-1} mg for 1,1,1-trichloroethane.

Accident ID C5. A single drum is dropped from a forklift. Due to the headspace gas release assumption, this is an identical scenario to C4. The concentration and intake ranges remain the same.

Accident ID C6. Two drums are punctured by a forklift. A third drum falls and ruptures as a result of the initial accident. Concentrations at a worker in the vicinity range from 2.5 mg/m^3 for methylene chloride to 7.0×10^{1} mg/m^3 for 1,1,1-trichloroethane. The estimated intake range resulting from a 15-second

TABLE 5.42 Releases, worker exposures, and estimated intakes from projected accidents during WIPP facility operations

Accident[a]	Chemical	Release (g)	Concentration at receptor[b] (mg/m^3)	Estimated intake[c] (mg/exposure)
C2	CCl_4	2.7×10^{-1}	5.8×10^{-1}	1.4×10^{-2}
	MeCl	6.9×10^{-2}	1.5×10^{-1}	3.7×10^{-3}
	TCA	1.9×10^{0}	4.1×10^{0}	1.0×10^{-1}
	Freon	1.8×10^{-1}	3.8×10^{-1}	9.5×10^{-3}
	TCE	1.0×10^{-1}	2.2×10^{-1}	5.4×10^{-3}
C3	CCl_4	8.2×10^{-1}	1.7×10^{0}	4.3×10^{-2}
	MeCl	2.1×10^{-1}	4.4×10^{-1}	1.1×10^{-2}
	TCA	5.8×10^{0}	1.2×10^{1}	3.1×10^{-1}
	Freon	5.4×10^{-1}	1.1×10^{0}	2.9×10^{-2}
	TCE	3.1×10^{-1}	6.5×10^{-1}	1.6×10^{-2}
C4/C5	CCl_4	2.7×10^{-1}	3.3×10^{0}	2.1×10^{-2}
	MeCl	6.9×10^{-2}	8.3×10^{-1}	5.2×10^{-3}
	TCA	1.9×10^{0}	2.3×10^{1}	1.5×10^{-1}
	Freon	1.8×10^{-1}	2.2×10^{0}	1.4×10^{-2}
	TCE	1.0×10^{-1}	1.2×10^{0}	7.8×10^{-3}
C6	CCl_4	8.2×10^{-1}	9.8×10^{0}	6.2×10^{-2}
	MeCl	2.1×10^{-1}	2.5×10^{0}	1.6×10^{-2}
	TCA	5.8×10^{0}	7.0×10^{1}	4.4×10^{-1}
	Freon	5.4×10^{-1}	6.5×10^{0}	4.1×10^{-2}
	TCE	3.1×10^{-1}	3.7×10^{0}	2.3×10^{-2}
C10	CCl_4	2.7×10^{-1}	3.3×10^{0}	2.1×10^{-2}
	MeCl	6.9×10^{-2}	8.3×10^{-1}	5.2×10^{-3}
	TCA	1.9×10^{0}	2.3×10^{1}	1.5×10^{-1}
	Freon	1.8×10^{-1}	2.2×10^{0}	1.4×10^{-2}
	TCE	1.0×10^{-1}	1.2×10^{0}	7.8×10^{-3}
	Lead	2.7×10^{-7}	4.3×10^{-8}	1.6×10^{-7}

[a] A detailed description of the accident scenarios is given in Appendix F.

[b] Modeled as a hemispheric cloud expanding at a rate equivalent to the ventilation flow rate in the accident area. The receptor concentration is specific to each accident scenario (Appendix G).

[c] Estimated intakes are based on the formula: Intake = Receptor Concentration x Respiratory Volume x Exposure Period x transfer coefficient. The transfer coefficient is assumed to be 1.00 for all volatile organic chemicals and 0.35 for lead. Respiratory volume is assumed to be 12 m^3/work day and the exposure periods are given in Appendix G.

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exposure is 1.6×10^{-2} mg for methylene chloride to 4.4×10^{-1} mg for 1,1,1-trichloroethane.

Accident ID C10. A spontaneous ignition event occurs in a single drum in an underground disposal chamber. To estimate exposures from this incident, it was assumed that all gases in the void volume of the drum were released instantaneously at ignition. The releases and exposures from this event were found to be identical to those for C4 and C5.

Estimations of particulate releases of lead have been made based on the vapor pressure of elemental lead. A concentration and intake were estimated for an aboveground individual at the point of maximum concentration as predicted by short-term air dispersion modeling for underground releases. Exposure to an underground worker to volatile organics and lead is not considered as a reasonably foreseeable event because of the duration of the event and the location of workers during the accident (Appendix F).

The release period was assumed to last for 30 minutes. Lead volatilization was estimated for a temperature of 1300°K (1027°C). Of the potentially vaporized lead, 0.25 percent was assumed to be released as an aerosol. As the heated aerosol encounters the cool bedded salt surface, a high deposition rate was predicted. This removal rate was assumed to be 80 percent. No credit was taken for HEPA filtration of the exhaust for the underground disposal area. These assumptions are consistent with the accident scenario for radiological exposures.

Using these assumptions in conjunction with the air dispersion modeling data produced an estimated aboveground receptor concentration of 4.3×10^{-8} mg/m^3 of free lead. The estimated intake resulting from 30 minutes exposure at this concentration is 1.6×10^{-7} mg.

5.2.4.5 Human Health and Environmental Consequences of Hazardous Chemical Releases. Estimated releases of and consequent exposures to potentially hazardous chemicals in TRU waste is related to potential risks to human health and the environment. In this assessment, risks to human health are expressed as incremental risks of excess cancers for carcinogenic chemical exposures. Exposures to noncarcinogenic chemicals are compared to established health-protective levels for noncarcinogenic exposures.

Estimation of Potential Risks from Routine Exposure to Carcinogens. Table 5.43 gives R_i values (incremental lifetime cancer risks) for the three carcinogens evaluated. Toxicological profiles and carcinogenic potency factors are included in Appendix G. For residential exposures, carbon tetrachloride has a total estimated excess cancer risk (i.e., the sum of aboveground and underground routine operations) of 5.3×10^{-10} for the Test Phase or slightly more than one excess case in a population of four billion. The total estimated excess cancer risk associated with potential residential exposures to methylene chloride during the Test Phase at the WIPP site was 2.0×10^{-11} or, at most, slightly more than one case in twenty billion population. Similarly, the maximum

total estimated cancer risk associated with trichloroethylene was 2.3×10^{-11} during this period. The estimated excess cancer risk associated with these chemicals during the 20-year operational program was within these same ranges, indicating no greater risk to the public during WIPP operations.

For occupational aboveground exposures at the WIPP facility during the Test Phase, the excess total cancer risk for carbon tetrachloride was estimated to be 6.5×10^{-10} (Table 5.43). Methylene chloride has a total estimated excess cancer risk of 2.4×10^{-11} (Table 5.43). The maximum excess cancer risk associated with trichloroethylene during this period was estimated to be 2.7×10^{-11}. Again, the risk associated with 20 years of operations was in a similar range.

For occupational underground exposures, the excess total cancer risk from carbon tetrachloride during the Test Phase is estimated to be 3.0×10^{-6} (Table 5.43). Methylene chloride has a total estimated excess cancer risk of 1.1×10^{-7} or, at most, nearly three orders of magnitude less than the 10^{-4} level. Trichloroethylene has a maximum total estimated cancer risk of 1.2×10^{-7} for this period. The estimated excess cancer risk associated with these chemicals during the Disposal Phase was within these same ranges, indicating no greater risk to underground workers during this period.

For comparison, the baseline cancer incidence in the United States is about 3 in 10 or (approximately 280,000 per 1,000,000), approximately 80 percent of which result in death attributable to the disease (American Cancer Society, 1988).

Estimation of Potential Risks from Routine Exposure to Noncarcinogens. The data base compiled from the Rocky Flats Plant and the Idaho National Engineering Laboratory waste profiles yielded two volatile organic noncarcinogens present in quantities of greater than one percent by weight. Risks associated with noncarcinogens are presented in terms of hazard indices (Appendix G). The estimated daily intakes of hazardous chemicals by the various exposed individuals given in Tables 5.39, 5.40 and 5.41 are divided by the acceptable reference levels [i.e., Acceptable Intake Chronic (AICs)], (EPA, 1986). The acceptable intakes for chronic exposure are included in Appendix G. Hazard indices (HI) of less than unity indicate levels of exposure below the AIC. Because of the low concentrations of these chemicals, no differences in hazard indices from aboveground operations were detected for residential exposed individuals or aboveground workers between the Test Phase and the operational period. The HI for 1,1,1-trichloroethane was 4.2×10^{-11} for residential exposures during aboveground operations (Table 5.44), and 1.2×10^{-10} for aboveground occupational exposures. The residential HI for 1,1,2-trichloro-1,2,2-trifluoroethane was 6.8×10^{-13}, while the HI for the aboveground worker was 2.0×10^{-12}. The chemical-specific HIs are, in every case, considerably less than unity.

The hazard indices for 1,1,1-trichloroethane exposures to the public and both above- and belowground workers are slightly higher from underground operations, although all calculated hazard indices are well below unity. The highest hazard index was 1.8×10^{-3} for 1,1,1-trichloroethane, associated with the hypothetical and unrealistic scenario of a worker remaining in a room with 6,000 drums for 8 hours/day, 240 days/year, for 20 years.

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TABLE 5.43 Maximum incremental lifetime cancer risks for routine releases[a]

	Hypothetical resident		Aboveground worker		Underground worker	
	5-yr	20-yr	5-yr	20-yr	5-yr	20-yr
I. Aboveground operations						
Carbon tetrachloride	3.2×10^{-13}	1.3×10^{-12}	2.1×10^{-13}	8.2×10^{-13}	NA	NA
Methylene chloride	1.2×10^{-14}	4.7×10^{-14}	7.5×10^{-15}	3.0×10^{-14}	NA	NA
Trichloroethylene	1.3×10^{-14}	5.3×10^{-14}	8.4×10^{-15}	3.4×10^{-14}	NA	NA
II. Underground operations						
Carbon tetrachloride	5.5×10^{-10}	2.5×10^{-10}	6.5×10^{-10}	3.0×10^{-10}	3.0×10^{-6}	1.2×10^{-5}
Methylene chloride	2.0×10^{-11}	9.2×10^{-12}	2.4×10^{-11}	1.1×10^{-11}	1.1×10^{-7}	4.3×10^{-7}
Trichloroethylene	2.3×10^{-11}	1.0×10^{-11}	2.7×10^{-11}	1.2×10^{-11}	1.2×10^{-7}	4.8×10^{-7}

NA = Not applicable. The underground worker is not exposed to releases of hazardous chemicals resulting from aboveground activities.

[a] Incremental lifetime Risk = [cancer potency factor (mg/kg/day)] [Estimated daily intake (mg/kg/day)] [lifetime correction factor]. The cancer potency factors used are: carbon tetrachloride 1.30×10^{-1} (mg/kg/day); methylene chloride 1.40×10^{-2} (mg/kg/day); trichloroethylene 1.30×10^{-2} (mg/kg/day) (IRIS, 1989). The lifetime correction factors used for residents are 5/70 years for the Test Phase and 20/70 years for the Disposal Phase, and for occupational receptors are (8/24) (240/365) (5/70) and (8/24) (240/365) (20/70), because exposures are assumed to be 8 hours per day, 240 days per year for the Test Phase and Disposal Phase, respectively.

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TABLE 5.44 Maximum hazard indices for routine releases[a]

	Hypothetical resident		Aboveground worker		Underground worker	
	5-yr	20-yr	5-yr	20-yr	5-yr	20-yr
I. Aboveground operations						
1,1,1-trichloroethane	4.2×10^{-11}	4.2×10^{-11}	1.2×10^{-10}	1.2×10^{-10}	NA	NA
1,1,2- trichloro-1,2,2-trifluoroethane	6.8×10^{-13}	6.8×10^{-13}	2.0×10^{-12}	2.0×10^{-12}	NA	NA
II. Underground operations						
1,1,1-trichloroethane	7.2×10^{-8}	8.2×10^{-9}	3.9×10^{-7}	4.4×10^{-8}	1.8×10^{-3}	1.8×10^{-3}
1,1,2-trichloro-1,2,2-trifluoroethane	1.2×10^{-9}	1.3×10^{-10}	6.3×10^{-9}	7.2×10^{-10}	2.9×10^{-5}	2.9×10^{-5}

NA = Not applicable.

[a] Hazard Index = Estimated daily intake (mg/kg/day) divided by Acceptable Intake Chronic (AIC) (mg/kg/day). The AICs (IRIS, 1989) for 1,1,1,-trichloroethane and 1,1,2-trichloro-1,2,2-trifluoroethane are 6.3 and 3.0×10^{-1} mg/kg/day, respectively. The oral AIC was used for 1,1,2-trichloro-1,2,2-trifluoroethane because an inhalation AIC was unavailable.

Estimation of Potential Risks from On-Site Accident Events. On-site accident scenarios all represent acute (i.e., exceedingly short-term) exposures. Reference levels were derived from chemical-specific Threshold Limit Values (TLVs) (ACGIH, 1986) and Immediately Dangerous to Life and Health (IDLH) criteria (CHEMTOX, 1988), and were used in calculating accident-related HIs. The exception to this is lead for which there is no IDLH. Tables 5.45 and 5.46 include the criteria-based reference levels and the risks associated with the release of hazardous chemicals from on-site accidents at the WIPP. The methodology used to determine the criteria-based reference levels is provided in Appendix G.

Occupational Risks from Aboveground Accidents. There are two hypothetical accident scenarios that are applicable to aboveground operations. Both of these accidents were postulated to occur in the WHB. Predicted exposures from these accidents are reviewed in Subsection 5.2.4.3. Detailed exposure estimates are given in Table 5.42.

Accident ID C2. A single drum is dropped from a forklift. The IDLH-based HIs range from 2.8×10^{-7} for methylene chloride to 2.5×10^{-5} for 1,1,1-trichloroethane (Table 5.45). The TLV-based HIs range from 1.0×10^{-7} for Freon to 4.0×10^{-5} for carbon tetrachloride (Table 5.46).

Accident ID C3. Two drums are punctured by a forklift. A third drum falls and ruptures as a result of the initial accident. The IDLH-based HIs range from 8.4×10^{-7} for methylene chloride to 7.6×10^{-5} for 1,1,1-trichloroethane (Table 5.45). The TLV-based HIs range from 3.1×10^{-7} for Freon to 1.2×10^{-4} for carbon tetrachloride (Table 5.46).

Occupational Risks from Underground Accidents. There are four hypothetical accident scenarios that are applicable to underground operations. All of these accidents were postulated to occur in underground disposal areas. Risks associated with these accidents were also included in Tables 5.45 and 5.46.

Accident ID C4. A transporter hits a pallet of drums in the underground disposal area. As a result, the lid is knocked off of one drum. The IDLH-based HIs range from 4.0×10^{-7} for methylene chloride to 3.6×10^{-5} for 1,1,1-trichloroethane. The TLV-based HIs range from 1.5×10^{-7} for Freon to 5.7×10^{-5} for carbon tetrachloride.

Accident ID C5. A single drum is dropped from a forklift. Because of the assumption that all of the gas in the void volume of a drum is released when a drum is opened, this is an identical scenario to C4. The IDLH-based HI and TLV-based HI ranges remain the same.

TABLE 5.45 IDLH-based hazard indices (HIs) for accidents during routine operations

Accident[a]	Chemical	IDLH[b] (mg/m^3)	IDLH-based allowable intake[c] (mg/exposure)	IDLH-based HIs[d]
C2	CCl_4	1,800	1,350	1.1×10^{-5}
	MeCl	17,500	13,125	2.8×10^{-7}
	TCA	5,429	4,071	2.5×10^{-5}
	TCE	5,400	4,050	1.3×10^{-6}
	Freon	34,200	25,650	3.7×10^{-7}
C3	CCl_4	1,800	1,350	3.2×10^{-5}
	MeCl	17,500	13,125	8.4×10^{-7}
	TCA	5,429	4,071	7.6×10^{-5}
	TCE	5,400	4,050	4.0×10^{-6}
	Freon	34,200	25,650	1.1×10^{-6}
C4/C5	CCl_4	1,800	1,350	1.5×10^{-5}
	MeCl	17,500	13,125	4.0×10^{-7}
	TCA	5,429	4,071	3.6×10^{-5}
	TCE	5,400	4,050	1.9×10^{-6}
	Freon	34,200	25,650	5.3×10^{-7}
C6	CCl_4	1,800	1,350	4.6×10^{-5}
	MeCl	17,500	13,125	1.2×10^{-6}
	TCA	5,429	4,071	1.1×10^{-4}
	TCE	5,400	4,050	5.7×10^{-6}
	Freon	34,200	25,650	1.6×10^{-6}
C10	CCl_4	1,800	1,350	1.5×10^{-5}
	MeCl	17,500	13,125	4.0×10^{-7}
	TCA	5,429	4,071	3.6×10^{-5}
	TCE	5,400	4,050	1.9×10^{-6}
	Freon	34,200	25,650	5.3×10^{-7}
	Pb	NA	NA	NA

NA = Not available. An IDLH for lead is unavailable, and therefore, lead is evaluated using a TLV-based allowable intake.

[a] A detailed description of the accident scenarios is given in Appendix F.

[b] CHEMTOX Data Base, 1988.

[c] The IDLH is the maximum concentration in air from which one could escape within 30 minutes without any physically-impairing symptoms or irreversible health effects (Sittig, 1985). Therefore, the IDLH-based allowable intake uses the formula in Appendix G with an exposure period of 30 minutes or 1/16th of the workday.

[d] IDLH-based hazard index = Estimated Intake (mg/exposure)/IDLH-Based Allowable Intake (mg/exposure).

TABLE 5.46 TLV-based hazard indices (HIs)

Accident[a]	Chemical	TLV-TWA[b] (mg/m^3)	TLV-based allowable intake[c] (mg/exposure)	TLV-based HIs[d]
C2	CCl_4	30	360	4.0×10^{-5}
	MeCl	175	2,100	1.7×10^{-6}
	TCA	1,900	22,800	4.5×10^{-6}
	TCE	270	3,240	1.7×10^{-6}
	Freon	7,600	91,200	1.0×10^{-7}
C3	CCl_4	30	360	1.2×10^{-4}
	MeCl	175	2,100	5.2×10^{-6}
	TCA	1,900	22,800	1.4×10^{-5}
	TCE	270	3,240	5.0×10^{-6}
	Freon	7,600	91,200	3.1×10^{-7}
C4/C5	CCl_4	30	360	5.7×10^{-5}
	MeCl	175	2,100	2.5×10^{-6}
	TCA	1,900	22,800	6.4×10^{-6}
	TCE	270	3,240	2.4×10^{-6}
	Freon	7,600	91,200	1.5×10^{-7}
C6	CCl_4	30	360	1.7×10^{-4}
	MeCl	175	2,100	7.4×10^{-6}
	TCA	1,900	22,800	1.9×10^{-5}
	TCE	270	3,240	7.2×10^{-6}
	Freon	7,600	91,200	4.5×10^{-7}
C10	CCl_4	30	360	5.7×10^{-5}
	MeCl	175	2,100	2.5×10^{-6}
	TCA	1,900	22,800	6.4×10^{-6}
	TCE	270	3,240	2.4×10^{-6}
	Freon	7,600	91,200	1.5×10^{-7}
	Pb	0.15	9	1.8×10^{-8}

[a] A detailed description of the accident scenarios is given in Appendix F.

[b] ACGIH, 1986.

[c] The TLV is a time-weighted average for an 8-hour period intended to protect workers over a career of exposure. Therefore, the TLV-based allowable intake uses the formula in Appendix G with an exposure period of 8 hours.

[d] TLV-based hazard index = Estimated Intake (mg/exposure)/TLV-Based Allowable Intake (mg/exposure).

Accident ID C6. Two drums are punctured by a forklift. A third drum falls and ruptures as a result of the initial accident. The IDLH-based HIs range from 1.2×10^{-6} for methylene chloride to 1.1×10^{-4} for 1,1,1-trichloroethane. The TLV-based HIs range from 4.5×10^{-7} for Freon to 1.7×10^{-4} for carbon tetrachloride.

Accident ID C10. A spontaneous ignition event occurs in a single drum in an underground disposal chamber. To estimate exposures to hazardous chemicals from this incident, it was assumed that all of the gases in the void volume of the drums would be released instantaneously at ignition. Because this accident involves the release of hazardous chemicals from one drum in an underground storage room, the IDLH-based HI and TLV-based HI ranges for the volatile organic compounds for this event were identical to those for C4 and C5 (Tables 5.45 and 5.46, respectively).

Estimates of particulate releases of lead were made based on the vapor pressure of elemental lead. An exposed individual concentration and intake were estimated for an aboveground receptor at the point of maximum concentration as predicted by short-term air dispersion modeling for underground releases. Using the assumptions given in Subsection 5.2.4.4, the TLV-based HI for lead is 1.8×10^{-8} (Table 5.46).

Residential Risks from On-Site Accident Events. The estimated HI ranges for workers in the near vicinity of each accident are provided above. For each accident, the maximum HI is at least three orders of magnitude less than unity. If hazardous chemicals were to be transported to the hypothetical individual at the site boundary as a result of atmospheric dispersion of any of the on-site accident releases, the dilution in the vastly increased air volume (coupled with the increased diffusion) would produce expected HI ranges with maximum values even less than the already very small HIs estimated for the occupational workers.

Consequences of Waste Retrieval. Hazardous chemical exposures from both routine and accidental releases during waste retrieval are postulated to be about the same as exposures during waste emplacement. The associated human health consequences would be in the same low range as those estimated during the Test Phase.

5.3 SEIS ALTERNATIVE ACTION

This subsection discusses the potential environmental consequences associated with the Alternative Action.[1]

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1 It should be noted that if lesser amounts of wastes are used in the Test Phase than postulated here, these risk analyses bound those impacts, and during the Disposal Phase the impacts would be nearer those calculated for the Alternative Action. Depending upon the quantity of waste actually emplaced during the Test Phase, the impacts of the Disposal Phase could be between those analyzed here and in Subsection 5.3.

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5.3.1 Biology

Conducting the bin-scale tests at the Idaho National Engineering Laboratory (or other DOE facility) would have very little impact on the general environment. The test facility would require less than 0.25 acre of land for construction. This small amount of land area should not significantly affect wildlife habitat.

Impacts associated with operation of the WIPP after the bin-scale tests would be the same as for the Proposed Action (SEIS Subsection 5.1.1).

5.3.2 Socioeconomics

Facility construction and operation would not significantly affect the work force or communities surrounding the Idaho National Engineering Laboratory (or other DOE facility). Design and construction of the bin-scale test facility was assumed to occur over a two-year period. Construction costs were estimated to be about $3.5 million. A large work force would not be required and could easily be attained from the available surrounding work force. Approximately 3,400 construction personnel are available within a 50-mile radius of the Idaho National Engineering Laboratory (DOE, 1988b). During construction, three to four associated test personnel would be required in addition to the construction force. After construction, there would be three years of testing and evaluation. During this period, the peak number of employees associated with the tests would be 11 plus some temporary duty professionals and personnel for waste preparation and handling. The existing infrastructure near the Idaho National Engineering Laboratory could easily accommodate the additional employees needed to conduct the test program. The 11 or so employees who would be added to the Idaho National Engineering Laboratory work force and payroll would not alter the existing socioeconomic structure in southeastern Idaho.

The greatest socioeconomic impacts from conducting the bin-scale tests at a location other than the WIPP are projected to occur in southeast New Mexico. If no wastes were shipped to the WIPP during the 5-year period of conducting bin-scale tests away from the WIPP, activity at the WIPP would decrease to maintenance levels. The FY 1990 through FY 1994 funding level would be decreased by a total of $80 to $90 million or about $13.5 million in FY 1990 and $18 million a year from FY 1991 through FY 1994. The number of jobs would drop by 105 in FY 1990 and another 30 to 40 in FY 1991 until FY 1995, at which time, if test results were positive, spending at the WIPP would increase to levels approximating those of the Proposed Action.

Additional costs of approximately $430 million are estimated to be necessary to bring the WIPP operation back to the level needed to start accepting waste, and would include costs of rehiring and training personnel and reactivating facilities and programs.

Under this approach, 100 percent of the waste would need to be disposed of between FY 1995 and FY 2013 as opposed to 90 percent in the Proposed Action. The annual disposal workload would increase from an average of 4.7 percent of wastes under the Proposed Action to 5.3 percent. This would require additional resources to meet the same goal. The additional costs would be $7.4 million a year, or $74 million over the Disposal Phase. Considering the combination of additional costs associated with varying activity levels and additional workloads, the total added cost could be $104 million. The net effect, additional costs minus net funding reductions of approximately $85 million, would be $19 million in constant dollars. The net cost in current dollars using a 3.5 percent projected inflation rate would be $66 million.

The reductions in activity that would occur from FY 1990 through FY 1994 would have a temporary negative effect on the regional economy that currently has not fully recovered from a decrease in activity levels in two basic industries (potash mining and oil and gas production). However, the additional efforts associated with the FY 1995 through FY 2013 period would increase the projected WIPP-related economic activity, employment, and personal income impacts by about 11 percent.

If the bin-scale tests could not provide adequate information for a decision to proceed with the Disposal Phase, one option would be to conduct room-scale tests at the WIPP. This would again increase the resources needed to operate the WIPP, particularly in the FY 2000 through FY 2013 period. Instead of an increase from 4.7 percent to 5.3 percent in annual waste disposal requirements, the annual percentage increases to 6.4 percent. While the disposal activity level for FY 1995 through FY 1999 would be lower (2 percent a year), there would be no appreciable change in funding needs since the room-scale tests would be conducted in this period. The additional cost over the Proposed Action is estimated to be about $206 million. The net effect, added costs minus net funding reductions, is estimated at $121 million in constant 1990 dollars. The current net dollar cost would be $261 million, using a projected 3.5 percent annual inflation rate.

5.3.3 Land Use

Conducting the bin-scale tests at the Idaho National Engineering Laboratory (or other DOE facility) would have very little impact on the land uses at that DOE facility. The facility would require less than 0.25 acre of land for construction, which is an insignificant amount of land area at the 890-mi^2 Idaho National Engineering Laboratory. The facility would, in all likelihood, be located near other active facilities at the Idaho National Engineering Laboratory and thus on previously disturbed areas. The land at the Idaho National Engineering Laboratory has been withdrawn from public use by the DOE and thus no conflicts with other planned uses are anticipated.

5.3.4 Air Quality

Air quality at the Idaho National Engineering Laboratory (or other DOE facility) would be temporarily impacted by the construction of the test facility. Additional emissions of engine exhausts and fugitive dust would occur. The engine exhaust emissions would

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be small compared to normal traffic on the Idaho National Engineering Laboratory site, and fugitive dust is normally minimized by applying water to the construction zone.

Normal operations of the facility could potentially result in the release of extremely small amounts of radionuclides. The building would be maintained under negative pressure and all exhausts would be through HEPA filters. The small amount of radioactive materials to be used for bin-scale tests and the controlled nature of the tests would further reduce the possibility of a significant radionuclide release. The facility would be constructed and operated in compliance with applicable DOE Orders, and State and Federal regulations.

Impacts associated with operation of the WIPP after the bin-scale tests would be essentially the same as for the Proposed Action, if it is determined to proceed with such operations.

5.3.5 Cultural Resources

Cultural resource impacts can be avoided by careful location of the facility. Any proposed location would have cultural resource surveys performed prior to initiating construction activities. Additional reconnaissance would be provided during those construction activities requiring land disturbance.

Impacts associated with operation of the WIPP after the bin-scale tests would be the same as in the Proposed Action.

5.3.6 Water Quality

No impacts to the hydrology or water quality would result from the facility. Run-off during construction would be controlled. The facility would not normally discharge liquids. Any accidental release would be contained by engineered features of the facility.

Impacts associated with operation of the WIPP after the bin-scale tests would be the same as in the Proposed Action.

5.3.7 Transportation

In the Alternative Action, only those tests that can be performed without placement of waste underground would be conducted until there is a reasonable expectation of compliance with regulatory requirements. TRU waste would not be transported to the WIPP until completion of the testing, which is projected to require about five years. Seven shipments from the Rocky Flats Plant to the Idaho National Engineering Laboratory (or other DOE facility) would be required for the bin-scale tests.[2] The estimated risks from occupational and nonoccupational incident-free exposures from these shipments are 9.8×10^{-6} LCFs, respectively.

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2 Assumed for purposes of analysis. These shipments would not be necessary if appropriate waste is already available at the facility.

5.3.7.1 Radiological Risks from Transportation. During the Disposal Phase, it was assumed for analysis that 100 percent of the TRU waste volume would be sent to the WIPP during a 20-year period. This would increase the rate of receipt and emplacement activities over rates projected for the Proposed Action. Exposures are calculated as discussed in SEIS Subsection 5.2.2.1. Estimates of releases and exposures associated with the increased rate of TRU waste shipments during the 20-year Disposal Phase are provided in Tables 5.47-5.49 (for Proposed Action, see Tables 5.10-5.12). Table 5.50 (for Proposed Action, see Table 5.14) provides the health risks associated with transporting TRU waste to the WIPP under the Alternative Action. The annual number of excess fatal cancers in the general public for combined CH TRU and RH TRU normal transportation operations and accidents in the population along a WIPP transportation corridor are 2.4×10^{-2} and 1.5×10^{-2} for truck and rail transportation, respectively. The total annual excess fatal cancers for combined CH TRU and RH TRU normal transportation for transportation workers are estimated to be 2.6×10^{-2} and 1.0×10^{-3} for truck and rail transportation, respectively. The annual risk to the hypothetical maximally exposed individual, in the 100% truck shipment case, are estimated to be 2.8×10^{-8} (0.028 chances per million) of contracting a fatal cancer for the person living near the roadway entering the WIPP ("off-link") and 4.2×10^{-5} for a person working for 10 years at a truck stop where all shipments stop ("stops"). For the maximum rail case, the risks are estimated to be 3.9×10^{-8} and 2.0×10^{-5} for "off-link" and "stops," respectively.

5.3.7.2 Nonradiological Risks from Transportation. In the Alternative Action, seven shipments from the Rocky Flats Plant to the Idaho National Engineering Laboratory would be required for the bin-scale tests. The bin-scale tests would be conducted over a 5-year period, and then TRU waste from all facilities would be shipped to the WIPP during a 20-year period. The estimated risk for truck shipments of CH TRU waste in the Alternative Action is 0.11 LCFs, 4.9 fatalities, and 63 injuries, as discussed in Subsection 5.2.2.3. For the rail mode, the estimated risk is 0.073 LCFs, 1.5 fatalities, and 16 injuries. The risks of shipping RH TRU waste for the Alternative Action are the same as for the Proposed Action and are presented in SEIS Subsection 5.2.2.3.

5.3.8 Radiological Assessment: Operations

Radiological exposures associated with conducting the bin-scale tests are expected to be small compared to present exposures at the Idaho National Engineering Laboratory (or another DOE facility) because the quantities of TRU waste associated with the tests are small. The facility for the tests would be sited, permitted, constructed, operated, and monitored in compliance with applicable regulations and standards.

TRU wastes would not be transported to the WIPP until completion of the testing which is projected to require about five years. Following the Test Phase, 100 percent of the TRU waste volume would be sent to the WIPP during a 20-year Disposal Phase, which would increase the rate of receipt and emplacement activities over rates projected for the Proposed Action. Estimates of releases and exposures associated with the increased rate of TRU waste receipt and emplacement during the 20-year Disposal Phase are provided in Tables 5.51-5.53 (for Proposed Action, see Tables 5.22-5.24). Releases and exposures were calculated using the same methods and assumptions provided in SEIS Subsection 5.2.3 and Appendix F, but with the higher annual waste throughput rates for operations associated with the Alternative Action.

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TABLE 5.47 Annual radiological exposures (person-rem) for CH TRU Alternative Action waste shipments to the WIPP[a]

	20-Yr Disposal Phase			
	100% Truck		Maximum Rail	
Facility	Occupational[c]	Public[d]	Occupational	Public
Idaho National Engineering Laboratory				
Normal	1.0×10^{1}	4.0×10^{0}	3.0×10^{-2}	3.0×10^{0}
Accident		1.6×10^{-1}		6.0×10^{-2}
Rocky Flats Plant				
Normal	1.5×10^{1}	3.8×10^{0}	5.0×10^{-2}	3.8×10^{0}
Accident		7.5×10^{-2}		3.6×10^{-2}
Hanford Reservation				
Normal	6.0×10^{0}	3.6×10^{0}	2.0×10^{-2}	3.1×10^{0}
Accident		1.6×10^{-1}		7.0×10^{-2}
Savannah River Site				
Normal	1.8×10^{1}	9.0×10^{0}	5.5×10^{-2}	8.0×10^{0}
Accident		5.5×10^{0}		2.6×10^{0}
Los Alamos National Laboratory[e]				
Normal	2.9×10^{0}	8.0×10^{-1}	2.9×10^{0}	8.0×10^{-1}
Accident		1.4×10^{-1}		1.4×10^{-1}
Oak Ridge National Laboratory				
Normal	1.5×10^{0}	2.3×10^{0}	1.2×10^{-2}	1.2×10^{0}
Accident		5.0×10^{-2}		2.4×10^{-2}
Nevada Test Site[e]				
Normal	2.0×10^{-1}	8.0×10^{-2}	2.0×10^{-1}	8.0×10^{-2}
Accident		3.6×10^{-5}		3.6×10^{-5}
Argonne National Laboratory - East				
Normal	9.0×10^{-2}	1.0×10^{-1}	6.5×10^{-4}	6.5×10^{-2}
Accident		3.4×10^{-4}		1.2×10^{-4}

TABLE 5.47 Concluded

Facility	20-Yr Disposal Phase			
	100% Truck		Maximum Rail	
	Occupational[c]	Public[d]	Occupational	Public
Lawrence Livermore National Laboratory				
Normal	8.0×10^{-1}	4.4×10^{-1}	2.9×10^{-3}	3.9×10^{-1}
Accident		9.0×10^{-3}		7.0×10^{-3}
Mound Laboratory				
Normal	1.4×10^{-1}	7.0×10^{-2}	4.1×10^{-4}	5.0×10^{-2}
Accident		2.1×10^{-4}		2.0×10^{-6}
Cumulative Risk				
Normal	5.5×10^{1}	2.4×10^{1}	3.2×10^{0}	2.0×10^{1}
Accident	---	6.0×10^{0}	---	3.0×10^{0}
TOTAL	5.5×10^{1}	3.0×10^{1}	3.2×10^{0}	2.3×10^{1}

[a] Annual exposures are calculated from the lifetime exposures presented in Appendix D by dividing by five years for the Test Phase and 20 years for the Disposal Phase (Proposed and Alternative Action).

[b] Assumes 10% of shipments from all generator sites completed during Test Phase; all shipments are made by truck.

[c] Occupational population is all the transportation crews.

[d] Nonoccupational population.

[e] Waste shipments limited to truck mode. Rail risks are the same as truck risks.

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TABLE 5.48 Annual radiological exposures (person-rem) for RH TRU Alternative Action waste shipments to the WIPP[a]

	Alternative Action 20-Yr Disposal Phase			
	100% Truck		Maximum Rail	
Facility	Occupational[c]	Public[d]	Occupational	Public
Idaho National Engineering Laboratory				
Normal	2.4×10^{0}	2.0×10^{0}	1.6×10^{-2}	1.6×10^{0}
Accident		3.9×10^{-2}		1.6×10^{-2}
Hanford Reservation				
Normal	2.1×10^{1}	4.1×10^{1}	2.2×10^{-1}	1.8×10^{1}
Accident		5.5×10^{-3}		2.7×10^{-3}
Los Alamos National Laboratory				
Normal	1.4×10^{-1}	6.0×10^{-2}	1.4×10^{-1}	6.0×10^{-2}
Accident		1.6×10^{-5}		1.6×10^{-5}
Oak Ridge National Laboratory				
Normal	1.4×10^{1}	1.0×10^{1}	9.0×10^{-2}	8.5×10^{0}
Accident		1.1×10^{-3}		6.0×10^{-4}
Argonne National Laboratory - East				
Normal	7.5×10^{-1}	6.0×10^{-1}	4.1×10^{-3}	3.8×10^{-1}
Accident		9.5×10^{-5}		3.9×10^{-5}
Cumulative Risk				
Normal	3.8×10^{1}	5.4×10^{1}	4.7×10^{-1}	2.9×10^{1}
Accident	---	4.6×10^{-2}	---	1.9×10^{-2}
TOTAL	3.8×10^{1}	5.4×10^{1}	4.7×10^{-1}	2.9×10^{1}

[a] Annual exposures are calculated from the lifetime exposures presented in Appendix D by dividing by 20 years for the Disposal Phase.

[b] At the time of preparation of this SEIS, no RH waste was assumed during the Test Phase; therefore, postulated exposures for RH waste shipments are the same for either scenario.

[c] Occupational population is the total transportation crews.

[d] Nonoccupational population.

TABLE 5.49 Estimated annual average exposure for the hypothetical maximally exposed member of the general public (nonoccupational exposure)[a]

	100% Truck Shipment Case[b]		
	Proposed Action		Alternative Action
	Test Phase (rem)	Disposal Phase (rem)	Disposal Phase (rem)
Off-Link[c]	2.7×10^{-5}	9.1×10^{-5}	9.8×10^{-5}
Stops[d,e]	1.5×10^{-1}	1.5×10^{-1}	1.5×10^{1}

	Maximum Rail Shipment Case[f]	
	Proposed Action (rem)	Alternative Action (rem)
Off-Link[c]	1.2×10^{-4}	1.5×10^{-4}
Stops[d,e]	7.2×10^{-2}	7.2×10^{-2}

[a] The Proposed Action transports the waste over a 25-year period, while the Alternative Action transports over a 20-year period.

[b] The annual average for the Alternative Action was calculated by assuming 100 percent of both CH and RH TRU waste is transported over a 20-year period.

[c] Calculated using RADTRAN-II model which assumes that individual is exposed to every waste shipment traveling at 15 mph at a distance of approximately 100 ft.

[d] Estimated exposure using a line source exposure model to a member of the public working at a truckstop (exposure distance of 65 ft and exposure duration of 2 hours) and assuming all trucks stop at that location, three shifts per day, and that individual works at location for 10 years.

[e] The total dose for "stops" assumes the person works for 10 years at the same job. Therefore, the annual average is one-tenth of the grand total value.

[f] The annual average for the Alternative Action was calculated by assuming 100 percent of the TRU waste is transported over a 20-year period.

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TABLE 5.50 Human health risks associated with radiological exposures during Alternative Action transportation to the WIPP

	Annual Health Risk[a,b,c] (latent cancer fatalities/year of operation)	
	Occupational	Public
Transportation Activity	Disposal Phase	Disposal Phase
100% TRUCK		
Normal	2.6×10^{-2}	2.2×10^{-2}
Accident	- - -	1.7×10^{-3}
TOTAL	2.6×10^{-2}	2.4×10^{-2}
Hypothetical maximally exposed individual[d] - Off-Link	- - -	2.8×10^{-8}
- Stops	- - -	4.2×10^{-5}
MAXIMUM RAIL		
Normal	1.0×10^{-3}	1.4×10^{-2}
Accident	- - -	8.4×10^{-4}
TOTAL	1.0×10^{-3}	1.5×10^{-2}
Hypothetical maximally exposed individual[d] - Off-Link	- - -	3.9×10^{-8}
- Stops	- - -	2.0×10^{-5}

[a] Transportation health risks are expressed as the annual number of excess fatal cancers estimated in the entire population along the shipping routes. (Both CH and RH TRU waste shipments are included.) Risks are expressed in exponential form; i.e., 1.0×10^{-3} is equivalent to 1.0 chance of a cancer in 1,000 for each year of operation.

[b] Risk of contracting fatal cancer: 2.8×10^{-4} fatalities/person-rem.

[c] Annual health effects risk estimates for genetic effects would be somewhat less than the risks presented in the table for cancer fatality risks as discussed in Appendix N.

[d] Risk expressed as chance of an individual member of the public contracting a fatal cancer due to the transportation of wastes to the WIPP. The assumptions are discussed in Appendix D, Subsection D.3.2.2.

TABLE 5.51 Routine radionuclide releases to the WIPP environment during the Alternative Action[a] (total activity in curies/year)

Radionuclide	WHB[b]	SE[c]
Co-60	7.1×10^{-14}	3.7×10^{-8}
Sr-90	2.1×10^{-12}	1.1×10^{-6}
Ru-106	1.5×10^{-14}	7.7×10^{-9}
Sb-125	4.6×10^{-16}	2.4×10^{-10}
Cs-137	1.8×10^{-12}	9.4×10^{-7}
Ce-144	1.4×10^{-13}	7.5×10^{-8}
Th-232	1.6×10^{-17}	1.2×10^{-12}
U-233	4.1×10^{-13}	3.2×10^{-8}
U-235	8.7×10^{-16}	2.5×10^{-10}
U-238	4.5×10^{-16}	7.6×10^{-11}
Np-237	5.4×10^{-16}	5.3×10^{-11}
Pu-238	2.6×10^{-10}	2.1×10^{-5}
Pu-239	2.2×10^{-11}	1.9×10^{-6}
Pu-240	5.1×10^{-12}	4.5×10^{-7}
Pu-241	3.9×10^{-10}	2.3×10^{-4}
Pu-242	8.3×10^{-16}	7.5×10^{-11}
Am-241	4.2×10^{-11}	4.4×10^{-6}
Cm-244	8.5×10^{-13}	7.1×10^{-8}
Cf-252	2.0×10^{-13}	2.2×10^{-8}
Total	7.2×10^{-10}	2.6×10^{-4}

[a] Based on annual throughput equivalent to about 44,000 CH drums and 400 RH canisters.

[b] WHB = waste handling building.

[c] SE = storage exhaust.

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TABLE 5.52 Annual radiation exposure to the public from routine operations during the Alternative Action

Activity	Alternative Action
Population[a] (person-rem) per year	1.2×10^{-3}
Population background (person-rem) per year	9.6×10^{3}
Maximum[b] individual (rem) per year	3.9×10^{-6}
Individual background (rem) per year	1.0×10^{-1}

[a] 50-year committed effective dose equivalent to population within 50 miles.

[b] 50-year committed effective dose equivalent at point of maximum air concentration.

TABLE 5.53 Annual occupational radiation exposure[a] from routine operations during the Alternative Action (person-rem/year)

Activity	Alternative Action
Direct radiation	15.8
Inhalation of airborne contaminants[b]	2.7
Total	18.5

[a] Exposures are total exposures to the entire waste handling crew.

[b] 50-year committed effective dose equivalent for one year of exposure.

Tables 5.54 and 5.55 (for Proposed Action, see Tables 5.29 and 5.30) provide estimates of the annual health impacts associated with routine and severe accidental radiological releases, respectively. As discussed in SEIS Subsection 5.2.3, the excess risk of incurring a fatal cancer was assumed to be 2.8 cancers per 10,000 person-rem of exposure to a population. To the worker population, the annual occupational excess risk of contracting a fatal cancer from routine operations is about 5.2 in 1,000 (5.2×10^{-3}) per year. The excess risk of contracting a fatal cancer to the entire population within 50 miles of the WIPP is 3.4 in ten million (3.4×10^{-7}) per year of normal operation distributed throughout the total population of 113,000. The hypothetical maximum individual is estimated to have slightly more than one chance in one billion (1.0×10^{-9}) per year of contracting a fatal cancer from living at the WIPP-site boundary.

The accident scenarios discussed in SEIS Subsection 5.2.3 for the Proposed Action are also appropriate for the Alternative Action. Table 5.55 (Proposed Action, see Table 5.30) shows health risks associated with radiation exposures during postulated accidents. An occupational worker will incur an estimated (1.7×10^{-3}) excess risk of contracting a fatal cancer if exposed to the most severe accident for worker exposure.

Health risks associated with the exposure to an individual beyond the secured area fence on the WIPP site following the most severe but credible accident for off-site exposure is about 4.8 in 10,000 (4.8×10^{-4}). An estimated 7.6×10^{-2} excess fatal cancers are projected among the 35,500 population within 50 miles of the WIPP in the westerly direction as a result of the 1,000 PE-Ci drum fire (Scenario C10). If the exhaust HEPA filtration system is activated, these risks drop by a factor of one million.

A beyond design basis accident (Scenario C8, hoist system failure) is discussed in Subsection 5.2.3.4 and in Appendix F.3. It is not considered to be a reasonably foreseeable event and is not further addressed in this subsection.

5.3.9 Chemical Assessment: Operations

This alternative involves only a limited volume of the waste located in an aboveground research facility at the Idaho National Engineering Laboratory or at another existing DOE facility. The design and operation of this facility would be in compliance with all applicable regulations pertaining to the management of hazardous waste as well as all required DOE Orders for the management of radioactive waste. The risks to human health and the environment from the operation of such a facility is expected to be minimal. If a decision were made to implement this alternative, more detailed analysis of the site-specific impacts would be conducted. Because the chemical risk assessment was not based on annual waste throughput rates but rather includes constant emissions of chemicals with receptors at locations of maximum exposure, the potential risks do not change for routine operations at the WIPP.

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TABLE 5.54 Population risks associated with routine radiological releases from WIPP operations during the Alternative Action[a,b,c]

Activity	Worker population
Facility operations	5.2×10^{-3}

Activity	General population
Facility operations	3.4×10^{-7}

[a] Health risks are expressed as the annual number of excess fatal cancers estimated in the entire exposed population as a result of WIPP-related activities. For perspective, average lifetime risk of any single individual contracting a fatal cancer is 2.2×10^{-1}.

[b] Risk of contracting fatal cancer: 2.8×10^{-4} fatalities/person-rem for each year of operation (BEIR, 1980).

[c] Annual health effects risk estimates for genetic effects would be somewhat less than the numbers presented in the table for cancer fatality risks as discussed in Appendix N.

TABLE 5.55 Maximum individual and general population risks associated with worst-credible accidental radiological releases from WIPP during the Alternative Action[a]

Activity	Maximum worker[b,c,d]
Facility operations	1.7×10^{-3}
Current risk of fatal cancer	2.2×10^{-1}

Activity	Maximum individual[b,c,e,f]
Facility operations	4.8×10^{-4}
Current risk of fatal cancer	2.2×10^{-1}

Activity	General population[c,f,g]
Facility operations	7.6×10^{-2}
Current risk of fatal cancer	7.8×10^{2}

[a] Health effects risk estimates for genetic effects would be somewhat less than the numbers presented in the table for cancer fatality risks as discussed in Appendix N.
[b] Health risks are expressed as the probability of an individual contracting a fatal cancer during his/her lifetime as a result of worst-credible accidental exposures. Risks are expressed in exponential form; i.e., 1×10^{-4} is equivalent to 1 chance in 10,000.
[c] Risk of contracting fatal cancer: 2.8×10^{-4} fatalities/person-rem
[d] Draft FSAR accident C3.
[e] Within the site boundary at the secured area fence.
[f] Draft FSAR accident C10.
[g] Health risks are expressed as the number of excess fatal cancers estimated in the entire exposed population of 35,500 located in the westerly direction (does not include the maximum individual)

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5.4 DECOMMISSIONING AND LONG-TERM PERFORMANCE

This subsection discusses the environmental effects of decommissioning the WIPP and the long-term performance of the WIPP as a repository for the permanent disposal of TRU waste. Calculations of long-term consequences are based on current technologies, social patterns, agriculture, diets, etc., because there is no credible rationale for selecting a likely future among the unknowable possibilities over the thousands of years considered. In effect, the SEIS uses the present era to illustrate a possible future.

5.4.1 Environmental Consequences of Decommissioning

Decommissioning consists of closing the facility, dismantling and removing the above-ground buildings (unless used for other purposes, see Subsection 2.6), entombing the underground portions of the facility by removing usable equipment, backfilling open tunnels and installing tunnel and shaft seals, and erecting monument markers.

The consequences of decommissioning the WIPP generally are estimated to be those described in the FEIS (Subsection 9.3.5). The decommissioning effort will be similar to a heavy construction project in that the same types of heavy equipment will be used. The impacts of using such machinery include an increase in nearby noise levels, increased levels of dust, and a temporary increase in local traffic.

There will be a temporary increase in local employment for the decommissioning force. The long-term socioeconomic effect, however, will be a decrease in the size of the work force once the decommissioning is complete.

The major resources to be expended in decommissioning will be water for decontamination and salt and possibly other materials such as bentonite for the backfilling operations. Fuels and electricity will also be consumed.

Decommissioning activities will be performed under controls that will ensure the safety of the general public and workers. Because decommissioning involves the disposal of contaminated equipment, it will potentially expose workers to radiation. Temporary shielding and extensive decontamination will reduce exposures to workers. The special procedures taken to protect the work force will also ensure that the more distant general public will be much less exposed.

5.4.2 Postoperational Performance

5.4.2.1 Changes from the FEIS. The FEIS examined five scenarios for the release of radionuclides to the environment (FEIS Subsection 9.7.1). Those scenarios involved hydraulic interconnections created by borehole drilling or other openings into or through the repository. At that time, it was believed that reasonably expected natural events would result in no release of radioactivity. Since then, the understanding of two factors important in undisturbed performance has changed: the rate of gas generation and the source and quantity of brine inflow.

First, gas generated by the waste and the surrounding container material was not thought to be important because the host-rock gas permeability was thought to be sufficiently high to allow dissipation. The FEIS states:

> These modes [of gas dispersion] have been tested by mathematical calculation using experimental values for gas permeability. Experiments show that the gas permeability [of the surrounding Salado salt], while not zero, is small enough for some accumulation of gas to be possible; the proper representation of the problem requires simultaneous consideration of the mine response with the gas generation. Some of these calculations have been completed. According to initial estimates based on them, there is little possibility of repository failure from overpressurization at gas-generation rates of less than 5 moles per year per drum. Since these conclusions depend on the gas permeability and the mechanical properties of the repository medium, they will be subject to some revision when data are available from actual underground workings (FEIS, p. 9-156).

It was thought that any gas generated would permeate into the surrounding Salado salt and not accumulate to the point that it would detrimentally pressurize the formation. Gas and brine permeability data obtained underground since 1980 indicate that the values assumed in the FEIS for gas permeability in undisturbed portions of the Salado are approximately three orders of magnitude too high.

Similarly, it was thought in 1980 that brine from the surrounding Salado Formation would be of little importance in the release of radioactivity. The attention was on fluid inclusions, which are small quantities of brine within individual grains of salt. It was known that these inclusions move in a thermal field toward regions of higher temperature. According to the FEIS:

> After a short time, less than a year, the temperature field around an assemblage of canisters will have become so uniform that the weak thermal gradient will bring no more inclusions to the canisters during the period of high heat production. . . .
>
> From experimental data, the total volume of fluid drawn to any canister can be estimated crudely; it may lie between 0.1 and 20 liters, with 0.1 liter more likely. . . .
>
> Rigorous verification of these expectations will require further investigations. Brine migration is now being studied in its entirety, both experimentally and theoretically. Current knowledge is sufficient to predict that brine migration will be of little concern in the WIPP repository, because no CH and little RH TRU waste stored there will produce significant thermal gradients (FEIS, pp. 9-158/159).

Fluid inclusions are still thought to be a minor source of brine inflow under the low projected thermal gradients in the repository, but experience underground has drawn attention to another source of brine inflow: intergranular brine. This brine was trapped

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between individual salt grains millions of years ago. Before the WIPP underground shafts and tunnels were mined (and at considerable distances from them still), formation brines were at high pressure, perhaps as high as lithostatic, i.e., under the weight of the overlying rock at 14 to 15 MPa (2,060 to 2,200 psi). When the shafts and tunnels were excavated, the pressure at their walls dropped to atmospheric pressure, 0.1 MPa (15 psi). A disturbed zone of higher porosity formed in the first few meters into the walls of these openings, and the intergranular brine moved toward the lower pressures in the excavation. This brine appears today as moist areas on tunnel walls that evaporate quickly into the dry underground air. Moisture builds up in some closed holes, and it would accumulate in the WIPP disposal rooms when they are closed. Brine inflow is also a factor that must be considered in scenario evaluation.

The FEIS considered five scenarios for the release of radioactive material from the WIPP repository (FEIS, pp. 9-124/125):

1) At some late time after decommissioning, a drill hole connects the Rustler aquifers above the repository with the Bell Canyon aquifer below, allowing water to flow up through the repository into the Rustler aquifers.

2) A pair of drill holes allows water to flow from the Rustler aquifers down through the repository and back up again into the Rustler aquifers.

3) A drill hole connects a stagnant pool in the repository with the Rustler aquifers, allowing migration of radionuclides upward by molecular diffusion.

4) A pair of connections form so large that all the Rustler water is diverted through the repository and back up into the Rustler aquifers. (This scenario was added to the list as a worst possible case; no processes that might form such connections were postulated.)

5) A drill hole intercepts a waste container, bringing radioactive material directly to the surface.

The fifth scenario treated material brought directly to the surface; the others were concerned with water-borne contaminants. Based on current understanding, these five scenarios are not considered to be fully representative of conditions that may affect long-term repository performance at the WIPP. The understanding of the site hydrology has changed, a quantitative analysis was not performed for a brine reservoir scenario, and none of the FEIS scenarios treats an undisturbed repository.

The scenarios presented in this analysis incorporate the following changes:

- The FEIS treated flow in the Rustler aquifer as if it were entirely porous-medium flow. Data taken since 1980 indicate that the flow is a dual-porosity flow, i.e., fracturing in the Culebra aquifer is also important.

- The FEIS evaluated the health effects resulting from discharge of contaminated Rustler water at its (presumed) natural discharge points in salt

lakes and the Pecos River 15 to 20 mi to the southwest of the repository. This SEIS considers a much closer release point, a hypothetical stock well about 3 mi (5 km) south of the center of the site.

- Long-term integrated releases of radioactive and nonradioactive substances from the WIPP controlled area have been calculated for the scenarios treated herein.

- Information obtained since the FEIS was published indicates that there probably is a pressurized brine reservoir in the Castile Formation under at least part of the repository (Earth Technology Corporation, 1987; Lappin, 1988). Therefore, release calculations in this SEIS assume that this reservoir is present.

- TRU waste was assumed to dissolve at the same rate as salt in salt-unsaturated brines entering the repository (an unrealistic assumption). In this SEIS, estimated solubility limits for waste radionuclides are used.

- The FEIS did not consider borehole seals typical of those used in the oil and gas industry in the intrusion borehole. Borehole seals, including a long-term increase in their permeability, are considered in the analyses presented herein.

- Marker Bed 139 (MB139), which in areas disturbed by mining exhibits a relatively high permeability, is a potential pathway past tunnel seals for the release of waste radionuclides.

5.4.2.2 Description of Approach and Data Selection. This SEIS evaluates two basic long-term release scenarios. These scenarios and their resulting impacts are intended to represent the range of impacts that could potentially result from the long-term disposal of TRU wastes at the WIPP. The first scenario (Case I) examines the expected long-term performance of an undisturbed repository. The second scenario (Case II) examines the expected long-term performance of a disturbed repository. Specifically, Case II examines a hypothetical intrusion into the repository by a borehole drilled through the repository into a pressurized brine reservoir below. Variations of Cases I and II are also examined by changing parameters such that less than expected (i.e., degraded) or better than expected (i.e., improved) repository performance results.

In Case IA, the properties of the waste and of the site and its surroundings were assigned expected values consistent with the studies outlined in Section 4 of this SEIS. (This is essentially the same long-term scenario that is presented in the No-Migration Petition [DOE, 1989c]). In Case IB, the flow and transport property values are intentionally degraded, (the flow is made easier), in order to evaluate the long-term repository behavior under undisturbed but more severe, less probable conditions. In Case IC, the tunnel and shaft seals performance is in addition to degraded flow and transport properties degraded in order to examine the consequences of a near-complete failure of those seals.

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In the April 1989 draft of this SEIS, four variations of Case II were examined. In Cases IIA and IIC, the intrusion scenario was examined under expected and greatly degraded conditions, respectively, without any mitigating measures such as compaction being used. In Cases IIB and IID, the degraded conditions remained, but potential treatments and engineering modifications were also postulated (e.g., compaction of the waste) to minimize the impacts of those consequences. The discussion of these four subcases is retained in this document.

Since the draft SEIS was prepared, additional data on the hydrologic properties of the Culebra aquifer have been analyzed and integrated into the overall description of that aquifer (see Subsection 4.3.3.2). In addition, the modeling of radionuclide transport in the Culebra has been improved by incorporating a more realistic two-dimensional treatment of that transport using the SWIFT II code (see Subsection 5.4.2.6). With these improvements, the two extreme cases, IIA and IIC, have been recalculated; these recalculated results are reported as Cases IIA(rev) and IIC(rev).

The improved description and modeling of Culebra flow and transport has also permitted an improvement of the calculations of integrated releases reported in the draft SEIS on pages 5-161 through 5-167. That earlier material has been replaced with new calculations of integrated releases in Cases IIA(rev) and IIC(rev).

In summary, these nine scenarios (Cases IA, IB, IC, IIA, IIA[rev], IIB, IIC, IIC[rev] and IID) predict the undisturbed and disturbed performance of the repository, under expected conditions and under more pessimistic assumptions.

Relative Importance of CH and RH Waste. These disturbed performance scenarios involve CH TRU waste only, not RH TRU waste. RH TRU waste differs from CH TRU waste principally in that it contains beta-gamma-emitting fission products (see Tables B.2.10, B.2.11, and B.2.12). The longest-lived of these fission products are Sr-90 and Cs-137, each of which has a half-life of about 30 years, and thus decays away early in the 10,000-year period covered in these calculations. For example, in 100 years, an average RH TRU waste canister would decay from 37 Ci to 12.7 Ci; its gamma-emitting nuclides would decay from 4.9 Ci to only 0.4 Ci, all the rest being nonpenetrating radiation--alpha and beta activity. Similarly a CH TRU waste drum would decay from 21 Ci to 7.9 Ci, all this being nonpenetrating radiation.

Sr-90 and Cs-137 may be of concern in the initial drill hole penetration into the repository, because some of the waste material would be brought immediately to the surface; but arrival times at the downstream stock well are in the order of hundreds to thousands of years, so the Sr-90 and Cs-137 would have decayed away and would not provide significant exposures.

RH TRU waste would be disposed of in individual canisters inserted into holes in the walls of the disposal rooms. As the surrounding rock closes in on the rooms, these canisters would remain physically separate from each other. On the other hand, the drums of CH TRU waste would be emplaced in contact with each other in the disposal rooms and would be crushed en masse. The contents would be intermixed, as the interconnecting porosity allows fluids to reach all the drums in the room. In contrast, the RH TRU waste canisters would remain physically isolated from each other and from the CH TRU waste rooms. Thus a drill hole passing through a CH TRU waste room

would allow brine to reach the whole room, or even a whole panel of seven rooms and two accessways, whereas brine in a drill hole passing through an RH TRU waste canister is assumed to have access only to that one canister.

The RH TRU waste stored in the WIPP would be a small target; all together these canisters would occupy only about 2 percent of the area of the CH TRU waste disposal rooms. Therefore, a drill hole would be much less likely to encounter an RH canister. In addition, the long-term consequences would be less severe, because the Castile brine flowing up the borehole is assumed to have contact with the radioactivity of only one canister. To contact more waste than one RH TRU canister, the brine would flow into the room and panel. This would be equivalent to the scenario of a borehole penetrating a room containing CH TRU waste. The RH TRU waste would not significantly affect the CH TRU scenario because RH TRU waste is less than 2 percent of the CH TRU waste by activity.

For these reasons, the CH waste alone would account for the principal long-term effects, and only CH waste is considered in the analyses of Cases I and II, with one exception: in all variations of Case II, the drill hole brings radioactive material to the surface, where the drill crew and people on a hypothesized nearby ranch are exposed to it. This direct release is analyzed for RH TRU waste as well as for CH TRU waste.

Calculations. Calculations start after a presumed 100-year period of effective institutional control with the waste disposal rooms closed and assume unchanging physical properties (e.g., seal permeability, waste porosity) thereafter. The base-case scenarios (Cases IA and IIA) use mid-range values for the various input data required. The rationales for and uncertainties of these input values are discussed in Appendix I.2. Quantitative calculations were carried out for 10,000 years consistent with 40 CFR Part 191, Subpart B. Exposures at later times are analyzed qualitatively on the basis of trends at the end of the calculations.

In each case, radiation doses to the maximally exposed individual are calculated. Some exposures are due to contaminated drilling mud and cuttings brought to the surface, where the person most exposed is the geologist who examines the cuttings. The radioactive material brought up in the drilling mud is discharged into a settling pond. It dries and is blown by the wind, exposing a hypothetical downwind ranch family. Other exposures result from radionuclides carried by groundwater to a hypothetical stock well approximately 3 mi south of the center of the WIPP site (see Appendix I.2.7), where it is postulated that cattle drink this water and people eat beef from those cattle. The stock well is taken to be at the nearest possible point downgradient where water usable by livestock might be found. The water at this well site is too saline for direct human consumption. The exposures at the stock well are those resulting from the maximum radionuclide concentrations to occur there within 10,000 years.

Lead is used as an indicator chemical in evaluating the potential long-term risks associated with the hazardous chemical constituents of TRU waste. The release of chemical constituents of the WIPP waste depends on, among other things, the initial concentration of the chemicals, the processes that may degrade or alter the chemical species present (e.g., biodegradation and radiolysis), the rate at which these processes progress, and the solubilities of the individual chemicals in the brine. Lead in the

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waste is not radioactive, although the prevalent chemical species may change because of changes in the repository environment. An estimate of a maximum lead solubility can be made based on equilibrium chemistry from the literature as described in Appendix I.1.4. The available information is insufficient to calculate a source term for hazardous organics.

Thermodynamic data and information on stable solid phase equilibrium chemistry for RCRA-regulated metals other than lead in a brine environment are not available, and therefore they cannot be evaluated by this methodology. Because lead is not expected to be limited by its initial concentration in the waste (WEC, 1989), it is conservatively assumed that the source term for stable lead is only limited by the solubility predicted by the EQ3NR model. Also, rapid dissolution of lead is assumed. Based on the estimated concentrations of other metals in TRU mixed waste (WEC, 1989), their solubilities may be limited in the brine because of their smaller inventories.

Information is also lacking in the scientific literature on the types and rates of reactions in the salt environment of the repository that would influence the organic chemical source term over a long period of time. It is known that processes that will tend to degrade organic compounds (e.g., biodegradation and radiolysis) will occur in the waste over the long term. However, the rates of degradation in this specific environment are not known. According to Clements and Kudera (1985), concentrations of volatile organic compounds in the headspace of drums containing TRU mixed waste are well below the saturation values for these compounds, indicating that the total concentrations in the waste must be limited. The DOE has no information to justify assumptions to estimate a source term for the organic chemicals in brine over the long term.

5.4.2.3 Narrative Descriptions of the Release Scenarios. Three versions of Case I have been examined. Each treats the performance of an undisturbed repository. Case IA examines its expected performance; Case IB examines its performance with degraded waste solubility and groundwater flow properties. Case IC, added since the draft SEIS was published, examines a still further degraded repository performance.

Case IA. In an undisturbed repository, the waste disposal tunnels are expected to close to nearly their final state in 60 to 200 years after decommissioning (Munson et al., 1989). Only near the end of this period will there be any appreciable resistance from the waste to the closure. The waste is assumed to compact to an estimated average final porosity of 15 to 21 percent (Lappin et al., 1989, Section 4.8).

The vertical shaft seals will consist of a salt column interrupted at several points by bentonite-and-concrete plugs (Figure 5.1) (see Subsection 6.3.2.3). The long-term integrity of the shaft seals depends on the lower salt section, which, like the underground tunnels, will be compressed by salt creep to about 95 percent of the salt's original crystal density within about 100 years. The upper salt sections, not being as deep and under a smaller weight of rock, will not consolidate as quickly.

Gas generated by microbial activity and radiolysis in the organic components of the waste and by corrosion of iron in the waste and waste drums is assumed to reach lithostatic pressure shortly after room closure has reached a near final state. Brine will

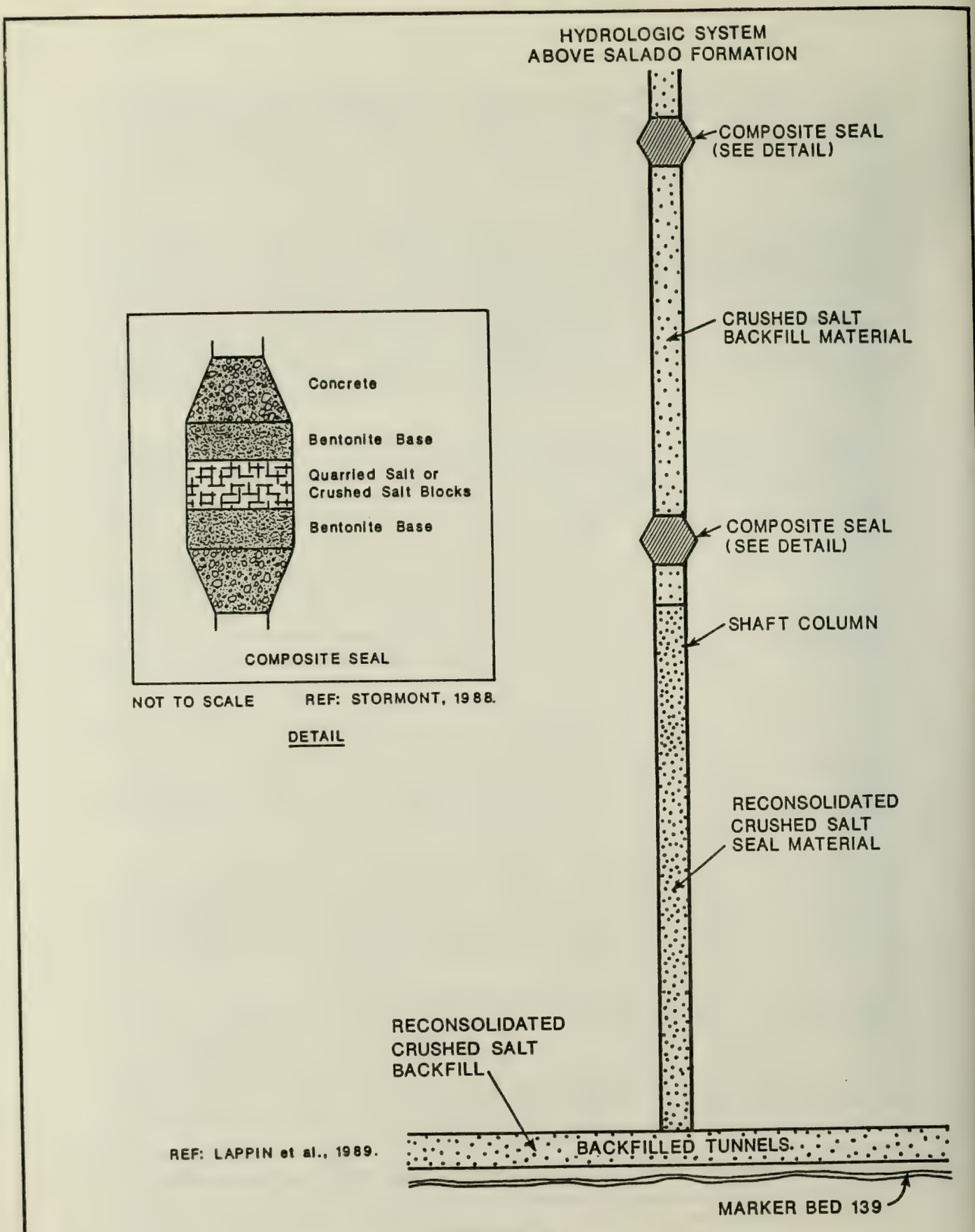

FIGURE 5.1
SCHEMATIC OF SHAFT SEAL SYSTEM IN THE SALADO FORMATION

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enter the rooms from the surrounding Salado Formation salt until the mounting gas pressure retards the flow. Bentonite clay will probably be added to the salt backfill to trap this brine.

Assuming that present estimates of gas generation rates are reasonable, then during the 100 years after the WIPP is decommissioned, gas will build up in the then-closed rooms faster than it can permeate out into the Salado salt. As the gas cannot escape into the Salado salt, its pressure will build up and one or more of the following may occur:

1) The disposal rooms may re-expand.

2) Gas may be stored in the disturbed rock zone around the rooms.

3) Gas may move into Marker Bed 139 and potentially up the shaft.

4) Gas may move either through or past panel seals and then up the shaft.

Some gas must leave the waste disposal area of the repository, since its pressure cannot build up to the point that it exceeds lithostatic, the pressure caused by the weight of the rock above. Re-expansion is improbable as long as other escape routes are available. Storage in the more distant parts of the Salado Formation is precluded by the low permeability of that rock.

Some gas will probably be stored in the disturbed rock zone (DRZ). This zone forms as a result of pressure release around the mined openings. During the latter part of room closure, the fracture porosity of the DRZ immediately around these openings will decrease, but the net amount of DRZ pore space will remain as small cracks distributed through the more distant parts of the host rock. In addition, some gas may escape through Marker Bed 139 (MB139) and in similar overlying layers, e.g., anhydrite "b" (see Figure 4.9b). MB139 is a short distance below the floor of the disposal rooms, and it constitutes a potential pathway for gas to bypass the panel seals. MB139 is a bed of broad extent; even away from the WIPP underground excavations where it has not participated in the formation of the DRZ, it has a permeability about 10 times greater than that of the rock salt portions of the Salado Formation (Tyler et al., 1988, p. 155). MB139 may allow gas to migrate to the bottom of the shafts, from where the gases may find a pathway upward, either to pass into other marker beds or to the surface. The volumes needed underground to accept all the gas that is generated and still maintain lithostatic pressure in the repository are discussed in Lappin et al. (1989, Section 4.10.2).

No harm will be done by any gas that escapes to the surface. The only radioactive gas possibly present is radon (Rn-222), a decay product in the Pu-238 chain. The decay of the 5.25×10^6 Ci of Pu-238 originally present in the repository (Table B.2.13) will cause its radioactive decay products to accumulate gradually. As a result, 25 Ci of Rn-222 will have accumulated in the repository at 1,000 years, 47 Ci will be present at 5,000 years, and 120 Ci at 10,000 years. Rn-222's half-life is only 3.8 days, so that any Rn-222 present in gases or liquids seeping out through the tunnels and shafts will

decay away before reaching the surface. Some radon will be released if an intruding borehole intercepts the repository, as analyzed in Case II below.

Lappin et al. (1989, Section 4.2) assume that gas will continue to be generated by corrosion for about 500 years and by bacterial action for about 2,000 years, until the iron and cellulosic materials from which they are generated are exhausted. The residual porosity of the repository rooms will then slowly fill with brine, and that brine will start to seep out to the base of the shafts and move upward through the consolidated salt in the shaft seals in response to pore pressure gradients.

The Case IA calculations estimate the rate and magnitude of these liquid-borne releases, assuming repository saturation at 2,000 years and steady-state hydrologic pressures and flow rates. Repository saturation may, however, take many thousands of years. The Case I calculations may therefore be conservative, since credit is taken for only 2,000 years of radioactive decay before saturation of the repository.

Case IB. This scenario treats the performance of an undisturbed repository with degraded radionuclide solubility and groundwater flow properties. Case IB differs from Case IA in that some parameters are degraded, including the solubilities of the radionuclides, which are assumed to be 100 times larger, and the resistance to flow in the shaft and panel seals, which is assumed to be a factor of 100 lower. Thus, the contaminated brine will meet less resistance to flow.

Case IC. This scenario was added to this final SEIS to evaluate concerns about the effects of the disturbed rock zone and the performance of tunnel and shaft seals. In this scenario, leakage through MB139 past the accessway seals is presumed to increase their permeability by another factor of 10 beyond what was assumed in Case IB. Also, leakage through the disturbed rock zone is presumed to increase the permeability of the lower shaft seal by a factor of 100 beyond what was assumed in Case IB. (In all three Case I scenarios the permeability of the upper shaft seal was already assumed to be large, 10^{-12} m^2 or 1 Darcy.)

Case IB and IC calculations, like those of Case IA, estimate the rate and magnitude of the liquid-borne radionuclide and stable lead releases, and also assume saturation and steady-state flow conditions.

Case II. Four versions of Case II have been examined. Each treats the performance of a disturbed repository. Case IIA examines its expected performance; Cases IIB, IIC, and IID incorporate (in various combinations) degraded properties of the stored waste and of the groundwater flow, and waste treatments. Cases IIA and IIC have been examined at two levels of sophistication in the models used; see Subsection 5.4.2.6 below.

In each case, it was assumed that a drill hole was inadvertently drilled into and through the repository. The likely reason is exploration for oil or gas in underlying strata. Notwithstanding the precautions to be taken to mark the site with a permanent monument on decommissioning and to leave records in appropriate archives, this scenario is fairly likely considering the long future before us; therefore, its consequences were evaluated.

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Assuming current drilling practices, the hole would be drilled by a rotary drill to depth and cased through the Rustler Formation down to the Salado salt. Drilling mud would be used to lubricate the drill bit and remove cuttings, and to prevent any dramatic release of pockets of gas underground.

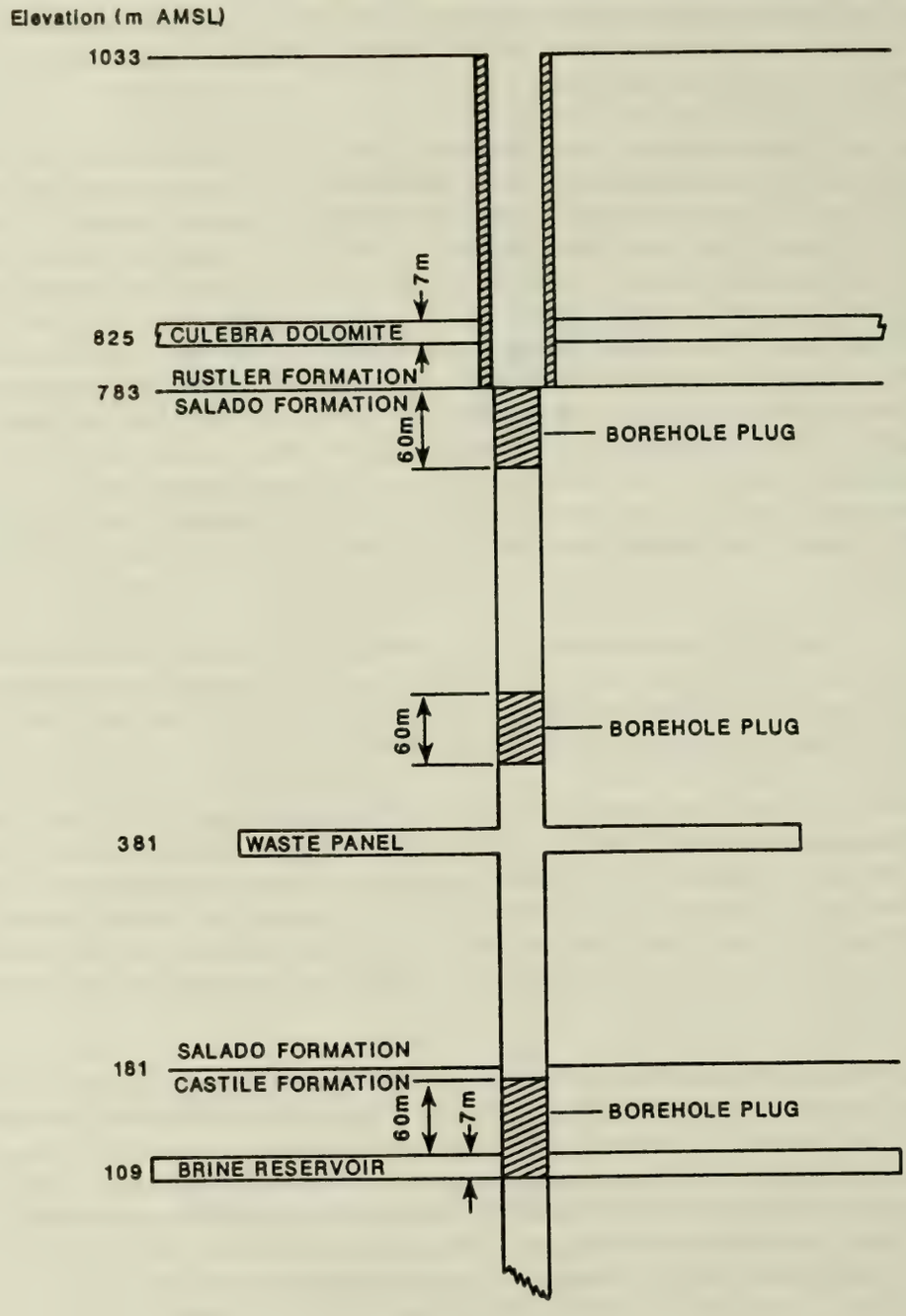
It was assumed that the repository would be breached at a time when the underground rooms containing the waste have closed to a thickness of about a meter. In Cases IIA, IIB, IIC, and IID, no credit was taken for radioactive decay before the breach occurred. In Cases IIA(rev) and IIC(rev) credit was taken for radioactive decay during 100 years of institutional control. Some radioactive material would be brought to the surface by the drilling mud, and the drilling mud would be contaminated by a small release of radon and other gases. These gases would be at lithostatic pressure in the compacted waste (whose porosity is 15 to 21 percent; see Appendix I.2.1). Most of the drill crew would only be exposed to a very low dose of radiation, because the contaminated gas and cuttings would be well mixed with the drilling mud and diluted, but any individual examining the cuttings closely would be somewhat more exposed. The contaminated cuttings and drilling mud would be discharged into a mud pit (a settling pond) where their residue after cleanup would eventually dry and be dispersed by the wind.

Drilling from the repository down to the brine reservoir in the upper Castile Formation (a distance of 270 m or almost 900 ft) would take about 15 hours. During this time the repository waste would be eroded by the circulating drilling mud, and additional radioactive material would be brought to the surface and dumped in the mud pit.

The assumed brine reservoir contains brine at a pressure of 12.7 MPa (1,900 psi), somewhat less than lithostatic, and the drill mud is at hydrostatic pressure for that depth (10 MPa or 1,500 psi). The 2.7 MPa pressure difference would tend to drive brine into the drilling mud and up to the surface. This would be evident to the drill crew as a flow of drilling mud from the hole or by the presence of gas, such as hydrogen sulfide. The flow would be stopped, both for safety reasons and economic reasons.

To re-establish control, the first action would involve the use of blowout preventers. The blowout preventer is closed either manually or hydraulically. If it is not closed, there will be no means of containing the pressure involved, no means of stopping further entry of formation fluid, and no way to get heavier mud into the hole. Otherwise, the drilling mud would have to be replaced, because it would be contaminated with brine or formation gases, and would require disposal. The drill crew would increase the drilling mud weight and stop the flow from the brine reservoir.

The drill crew would seal off the brine reservoir and drill on to the target depth in the Bell Canyon Formation. Later, when the oil or gas tapped by the hole was exhausted or if the hole proved to be dry, as much casing as possible would be pulled from the hole, and the hole would be plugged. When abandoned, the boreholes would have to be plugged according to the regulations of the New Mexico Oil and Gas Commission, which in southeastern New Mexico are intended to protect the potash beds from foreign fluids. It was assumed that the boreholes drilled through the repository would be plugged as shown in Figure 5.2.



REF: LAPPIN et al., 1989.

FIGURE 5.2

REPRESENTATIVE PLAN FOR PLUGGING A BOREHOLE THROUGH THE REPOSITORY TO A CASTILE FORMATION BRINE RESERVOIR

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Industry experience indicates that grout plugs do not maintain good seals for very long (Lappin et al., 1989, Appendix C); all Case II versions assume intact plugs for 75 years, followed by deterioration to the permeability of a rubble-filled hole in another 75 years. As these plugs fail, brine would start to flow up through them to the Culebra aquifer in the Rustler Formation, and at the same time, a lesser amount would flow down to the Bell Canyon Formation, because the Bell Canyon is at a lower hydraulic pressure than the brine reservoir in the Castile. (For this SEIS, however, all flow is assumed to be upward.) The upward flow would be slow enough, and the waste section permeable enough for the reservoir brine to come to equilibrium with the waste in the repository. The brine would thus become saturated with waste radionuclides and stable lead. In addition, brine inflow from the surrounding Salado Formation salt (1.3 m^3/yr per panel for Cases IIA, IIB, IIC, IID; 1.4 m^3/yr for Cases IIA[rev] and IIC[rev]) would be mixed with brine reservoir fluid and move up with it to the Culebra aquifer. The radionuclides and stable lead that get into the Culebra aquifer would flow to the south with the Culebra water, but not as fast, because they would be retarded to various degrees by sorption in the rock through which they pass.

Culebra water was assumed to be used off-site to water cattle. A stock well was hypothesized at the closest possible point to the WIPP that might yield usable (stock-potable) water (water with no more than 10,000 mg/L total dissolved solids). This point was estimated to be 3 mi to the south of the center of the WIPP site (Appendix I.2.7).

All Case II calculations start by estimating the radiation doses and lead exposures to the individual most exposed to the cuttings brought to the surface by the drill hole, and the exposures of the downwind ranch family. All calculations were made for a period of 10,000 years. Exposure levels at later times are considered qualitatively.

Case IIA. In this expected-case scenario, the arrival times and resulting maximum contamination levels (within 10,000 years) were calculated at the hypothetical downgradient stock well where some beef cattle would get their drinking water. It was assumed that people would use these cattle as their only source of beef and would thereby be exposed to radiation and dissolved lead.

Case IIB. This scenario treated the expected performance of a disturbed repository with degraded radionuclide solubility and groundwater flow properties. Case IIB also differs from Case IIA in that the WIPP waste was assumed to be compacted before emplacement to near-solid density. This resulted in a much less porous and less permeable waste mass. The brine passing up the borehole from the Castile reservoir was assumed to pass by the level of the waste room without mixing with its contents. However, brine inflow from the Salado Formation salt would continue. This formation brine would be saturated with waste radionuclides and lead (the former assumed to be 100 times more soluble than in Case IIA), would mix with the upflowing brine, and would flow up into the Culebra aquifer. There the matrix porosity was assumed to be 56 percent lower than in Case IIA (7 instead of 16 percent porosity) and the fracture spacing and fracture widths larger by a factor of 3.5 (Appendix I.2.6). These and other degraded parameters would increase groundwater flow and solute transport rates in the Culebra. Case IIB takes credit for waste compaction and grouting in eliminating free entry of Castile brines into the repository, but does not take credit for any reduction of inflow from the Salado Formation that might result from this compaction and grouting.

Case IIB calculations, like those of Case IIA, estimated the maximum radiation doses (within 10,000 years) to the maximally exposed individual at the ground surface near the drill hole. They also estimated the contamination levels from material that would enter the food chain from contaminated water drawn from the hypothetical down-gradient stock well for cattle to drink.

Case IIC. This scenario also treated the performance of a disturbed repository, predicting the maximum doses to humans that would occur within 10,000 years. It differs from Case IIB only in that the WIPP waste was not compacted, so that the brine passing up the borehole from the Castile reservoir would be able to reach solution equilibrium with the waste in the repository. Until the radionuclides start to become depleted, the Castile brine reaching the Culebra aquifer is saturated (to 10^{-4} molar) with waste radionuclides.

Case IID. This scenario also treated the performance of a disturbed repository, predicting the maximum doses to humans that would occur within 10,000 years. In it the waste was pretreated as in Case IIB, but it differs in that 1) the solubility of the radionuclides was taken as 10^{-6} molar, as in Case IIA, and 2) the only brine inflow considered was that which flowed into the room penetrated, not into an entire panel.

Cases IIA(rev) and IIC(rev). These two scenarios differ from Cases IIA and Cases IIC principally in that an improved version of the SWIFT II code was used that allows for explicit treatment of the two-dimensional nature of the flow and solute transport in the Culebra. These two were chosen to be recalculated because they are the extremes of the earlier scenarios.

5.4.2.4 Analysis of Scenarios: Initial Conditions.

Tunnel Closure. Closure is the crucial process that must occur in order for waste to be effectively encapsulated in the WIPP. Knowing how quickly a room will close and entomb the waste is essential in determining the performance of these rooms. This process results from the creep of the salt, which crushes the waste and backfill mixture into a compact mass.

Prior to mining the excavations underground, it was assumed that the final state of the waste emplaced in the WIPP, in the absence of human intrusion, would be compacted and dry (FEIS, Subsection 9.7.3.2). This assumption was based on the best conceptual models and data available at that time.

The observed closure behavior is not that simple. It is both more rapid and more complex than expected prior to actual mining. In fact, the total macroscopic closure to date is about three times that originally expected. Ignoring possible complications, the more rapid closure results in an estimated time of 60 to 200 years for closure to the final state.

There are several structural effects or processes due to excavation that were not anticipated in the FEIS. The process of excavation has resulted in the formation of a disturbed rock zone near the repository level (Borns and Stormont, 1987). At present, the significantly disturbed zone extends about 10 ft from the tunnel surfaces, depending on the size and age of individual tunnels. It has not been possible to include excavation effects in numerical modeling to date.

The characteristics of the disturbed rock zone include: 1) a volumetric dilatation or expansion caused by openings between grains, 2) macroscopic fracturing from previous fractures opening and from new ones forming, 3) order of magnitude increases in apparent permeabilities, 4) decreased mechanical strength of the salt, and 5) development of zones of partial saturation.

The present model of the closure behavior of the formation is markedly improved over that used before access underground (Munson et al., 1989). First, based on theoretical concepts, it was recognized that the mechanisms controlling salt creep are better described using a maximum shear (Tresca) criterion rather than the commonly used octahedral (von Mises) criterion. Also important are an improved small strain constitutive model, an improved set of material parameters, and a stratigraphy modified to better describe the conditions at the WIPP.

The model is based on the interpretation that coherent creep (i.e., movement of the rock mass as a whole rather than by the formation of fractures) of the Salado Formation salt will dominate the system, independent of the disturbed rock zone. The model assumes that 1) the disturbed rock zone is of small importance relative to the much greater volume of the deforming portions of the Salado Formation, and 2) the disturbed rock zone developed during excavation will be healed during the final stages of closure. Mechanical back pressures, especially if the disturbed rock zone has expanded to include the anhydrite marker beds, will not occur until very late in the closure process. A more sophisticated level of understanding based on underground observation of excavation effects also assumes that coherent creep of the Salado Formation outside the disturbed rock zone is the major structural process involved in the closure. However, the observed effects suggest that the disturbed rock zone may be involved in the closure by:

- Serving as a "sink" for some of the brine that seeps into the facility
- Creating a larger effective room size, increasing the time required for closure and the volumes available for brine inflow
- Affecting the final state of closure by extending to intersect the relatively brittle MB139 and other more permeable units above or below the repository level
- Providing discrete fractures that might be propped open by high gas pressures
- Degrading the expected post-emplacement performance of seals in tunnels and shafts.

It is now also known that there are strong structural members in the waste, such as pipes and rods. This implies a limit to the ultimate compaction of waste and backfill under lithostatic load (see Appendix I.2.1).

The remaining uncertainties concerning the mechanical behavior of the Salado Formation during closure of the WIPP repository, and hence the possibility of a more sophisticated treatment of this closure, do not imply the need for new physical insights to be incorporated into the conceptual models. Far-field coherent creep of the Salado Formation salt is still the dominant process involved. The present uncertainties concern only the time-dependent extent and the importance of the disturbed rock zone.

A calculation was made of how rapidly the closure would decrease the open volume of a waste disposal room. The calculated rate of closure of an empty disposal room (Munson et al., 1989) was used to determine the volume of empty space (voids) at a given time. The void volume was obtained by subtracting the volumes of the solids in the waste, the solids in the backfill, and the volume of brine flowing into the room (as a function of time; from Nowak et al., 1988) from the room volume.

An assumption in using empty room closure data for this estimate was that any backstress by the room contents would be insufficient to retard the closure until near its end. This assumption appears to be warranted because finite-element calculations show that backstress is significant only during the very last stages of closure (Sjaardema and Krieg, 1987). The no-backstress assumption is also consistent with the current model for compaction of the waste, which assumes that the final void volume depends only on the stress applied to the waste, and not the stress history; that is, the only effect of backstress is to prolong the time required to achieve the final compacted state. Estimates using these assumptions show that the final void volume will be achieved in 60 to 200 years, and the amount of brine flowing into the room during that time will be of the order of 6 to 37 m^3 (Nowak et al., 1988; Lappin et al., 1989, Section 4.3.1), far less than would be required to saturate the total of 123 m^3 (see Table I.2.1 in Appendix I) of final void volume. Figure 5.3 shows the results of these calculations of room closure, and Figure 5.3a shows how backpressure from gas and from the room contents affects the final stages of room closure. All of this brine can be sorbed if there is about 30 percent bentonite in the backfill (Lappin et al., 1989, Section 4.8.1).

The permeability of the room contents is needed, at least roughly, so that the ability of brine to flow through it can be estimated. This permeability is influenced by the large difference in estimated hydraulic conductivity for the three waste categories of sludge, combustibles, and metals and glasses. The computation of a net hydraulic conductivity depends on whether the brine flows through it by paths that are in parallel or in series: the sludge conductivity dominates the series path case with an estimated average conductivity of 4×10^{-9} m/s, and the metal waste conductivity dominates the parallel paths case with an estimated average conductivity of 4×10^{-6} m/s (Lappin et al., 1989, Section 4.8.2). It is unlikely that the waste is distributed uniformly enough within the room to presume parallel flow processes; however, flow in parallel is conservatively implied in assuming a net hydraulic conductivity of the room contents in the order of 10^{-6} m/s.

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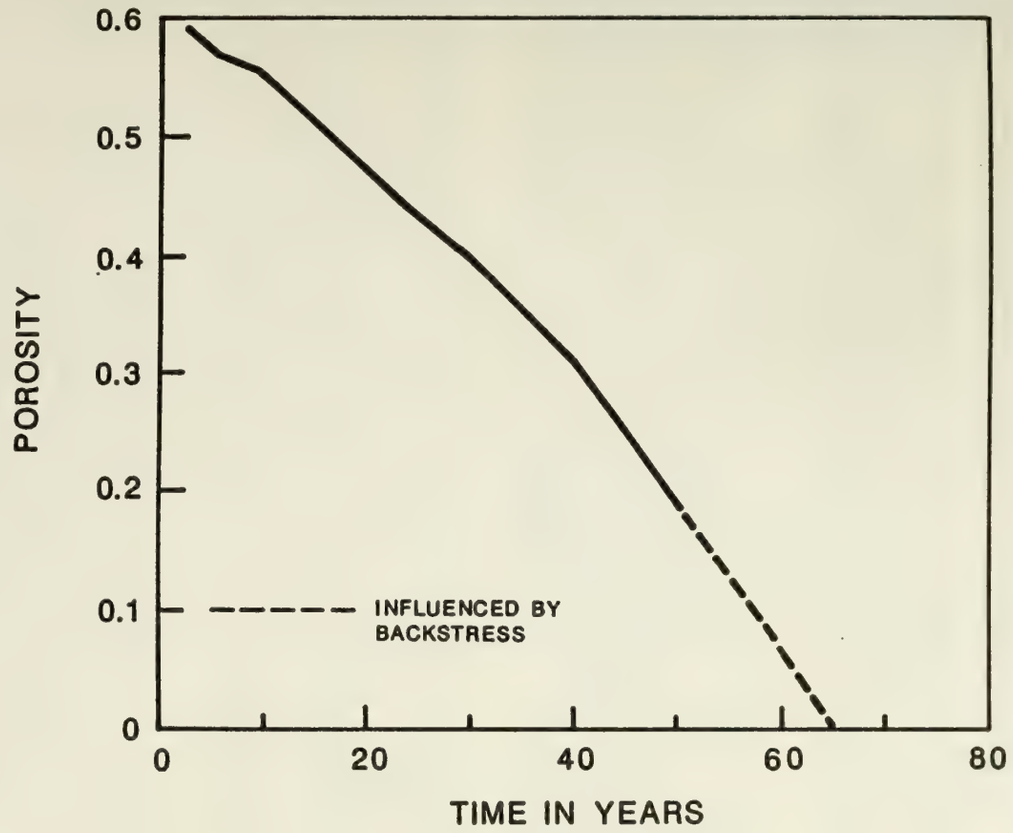
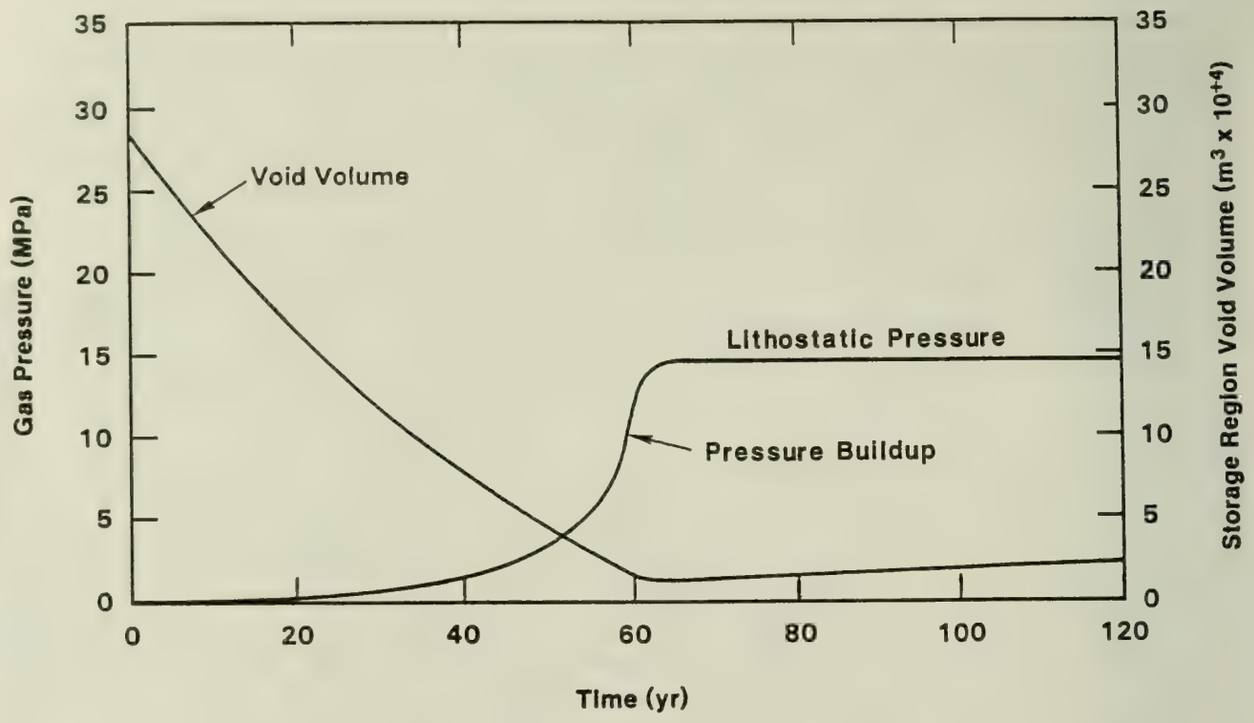


NOTE: THE BACKFILL IS ASSUMED TO BE 70% SALT, 30% BENTONITE WITH AN INITIAL DENSITY OF 1300 Kg/M^3.

REF: LAPPIN et al., 1989.

FIGURE 5.3
VOID REDUCTION DURING ROOM CLOSURE



REF; LAPPIN et al., 1989.

FIGURE 5.3a
PRESSURE HISTORY TO INITIAL CLOSURE OF STORAGE AREA, SHOWING THE EFFECTS OF GAS AND WASTE BACKPRESSURE

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The net conclusions of these studies are :

- The rooms will reach full closure in 60 to 200 years
- The final room porosity will range from 15 to 21 percent
- Marker Bed 139 will not be healed by closure.

Seal Compaction. Tunnel seals will be emplaced at the entrances to each of the eight waste disposal panels, in the main access ways at the head of the first four panels and on the shaft side of the access ways of all eight panels (Figure 6.1) The purpose of these seals will be to isolate the panels from each other and from the shafts to the surface. Shaft seals will also be emplaced (Subsection 6.3.2.3).

The tunnel seals will consist of reconsolidated crushed salt, possibly in the form of salt blocks. This salt will be held in place by end caps. These end caps are not expected to maintain their integrity in the long-term; they serve only as a short-term barrier to keep the salt in place until tunnel closure consolidates it to its final density (Stormont, 1988; see also Appendix E, Subsection E.9).

Calculations of seal reconsolidation have shown that crushed salt offers little resistance to creep closure until it has reconsolidated to 95 percent of the density of intact WIPP salt (Sjaardema and Krieg, 1987). Therefore, assuming no retardation of room closure, crushed salt backfill in the underground drifts is expected to reconsolidate in about 100 years to 0.95 relative density. Laboratory tests have shown that the permeability of reconsolidated crushed salt decreases monotonically with increasing relative density and reaches a permeability of 1×10^{-20} m^2 at 0.94 relative density (Holcomb and Shields, 1987).

Only small-scale seal performance tests have been conducted in situ at the WIPP (Peterson et al., 1987). These tests yielded an average effective permeability of 4×10^{-19} m^2 and a porosity of 0.03. However, uncertainty still remains regarding the long-term performance of full-scale seals. Therefore, in an attempt to bound this uncertainty, a MB139 seal permeability of a factor of 1000 higher, 4×10^{-16} m^2, was used for calculations in the degraded Case IC. During the Test Phase, large-scale seal performance tests will be conducted to reduce the uncertainty associated with long-term seal permeability.

Brine Inflow. The FEIS recognized that the WIPP salt is not completely dry (FEIS Subsection 9.7.3.2). Water was assumed present only in fluid inclusions within individual grains and in hydrous minerals. The FEIS principally treated brine that migrates toward heat sources. However, bedded salt is not pure on a macroscopic scale. It is now known that intergranular brine plays a primary role, as does water in other materials such as clays, and that this brine will move from the host rock toward the lower pressure of the open waste disposal rooms.

A model has been developed for predicting the movement of brine into the WIPP excavations from the surrounding rock salt (Nowak et al., 1988). This model is based on Darcy flow (flow according to Darcy's Law), a well-known and accepted method of

describing fluid movement in porous materials. The values used for model parameters are consistent with independent measurements of brine and host rock properties, and the brine movements calculated with the model are consistent with data on brine accumulations in test boreholes over periods of 2 to 3 years.

The capacity of the host rock salt to allow fluid flow through it under the driving force of pressure gradients, known as the "permeability," is very small at the WIPP, in the range of 1 to 10 nanodarcies (10^{-21} to 10^{-20} m^2). This range of permeabilities is consistent with in situ fluid flow measurements (Nowak et al., 1988).

Darcy flow in geologic materials is well understood, and the mathematical formalism describing it is accepted by the scientific community. In Darcy flow, fluid flows in the direction of lower pressure by relationships including the effects of permeability, fluid viscosity, and the elastic properties of the solid and fluid. In some circumstances, the solution to the advective-diffusive flow equation can be written out explicitly, being directly analogous to the diffusion of heat through solids.

The use of the present Darcy flow model for estimating brine inflow at the WIPP involves several assumptions:

- A network of interconnected pores in the surrounding salt extends outward without bound. Brine flows through the host rock from the near-infinite volume of host rock; its amount is not just limited to the amount present in the disturbed rock zone.

- The porosity and permeability of the salt remain constant.

- Brine pressures in the formation beyond the disturbed rock zone are lithostatic, i.e., the pressure implied by the weight of the rock above it. The use of lithostatic pressure, rather than something between that and hydrostatic, provides an effective upper bound on the inflow

- Brine flow is radially symmetric. The effect of features, such as the ends of rooms, is to strengthen the flow there, because the ends draw in brine from a greater volume of the formation

- Backstress from the room contents is negligible until near the end of the closure (Figure 5.3a).

Prediction of brine inflow cannot be undertaken without the use of physical models, because of the limitations of the tests that have been performed to date. For example, measurements have only been made in boreholes of small size. These must be extrapolated to predict brine inflow into large excavations. Furthermore, only models can be used to extrapolate from tests done on a short time scale to much longer periods of time. A model is necessary to translate the brine flow pattern around a test borehole and its change with time into predictions of the brine flow pattern and its long-term time history around a waste disposal room.

A series of analytical brine-inflow calculations have been made using geometries that approximate the WIPP configuration (Nowak et al., 1988). The results of these calculations are given in Table 5.56. The figures tabulated are for a period of 200 years, assuming no resistance to inflow during that period. In actuality, the room walls will have closed in on the waste in 60 to 200 years, and gas generated by the waste may have built up to lithostatic pressure, stopping the inflow. The lateral, semi-infinite entry in Table 5.56 (line a) considers a rectangular cross-section tunnel in a layered medium such that brine inflow cannot come from above or below, but must come from either side. The lateral finite entry (line b) considers inflow to one room among an array of similar rooms separated by pillars of finite width. In this case, brine can only be drawn from the volume of salt half the distance to the next room. The radial entry (line c) considers inflow to an isolated tunnel (assumed round for ease of calculation) from all the space around it.

TABLE 5.56 Cumulative volume of inflow at 200 years (m^3) for two values of permeability (k)

Model	$k=10^{-21}$	$k=10^{-20}$
Lateral semi-infinite[a]	0.7	2.3
Lateral finite[b]	0.4	0.4
Radial[c]	6.7	40.6
Line sink[d]	2.6	26.3

[a] Isolated tunnel with flow confined between upper and lower strata, no adjacent rooms.

[b] Same as [a], but with other rooms nearby.

[c] Radial flow to an isolated tunnel.

[d] Steady-state flow to an isolated tunnel.

The line-sink entry (line d) considers the inflow into a round tunnel at longer times, when the inflow has approached a steady-state. This fourth calculation yields a smaller brine inflow than the third, because the rapidly changing rate of flow at times soon after excavation is not included.

The largest of these volumes is 40.6 m^3 in 200 years. Because that figure is only 1.2 percent of the initial room volume, it would appear that brine inflow will have little effect on room closure. A more exact numerical calculation of inflow into a rectangular cross-section room (4 x 9 m) in an array of similar rooms yields an inflow of 43 m^3 in 100 years (Nowak et al., 1988).

Brine sorption is an important function of backfill. The addition of bentonite to crushed salt is being examined for its ability to sorb water. The focus is on a mixture of 70 percent crushed salt and 30 percent bentonite. The current estimate is that between 40 and 80 m^3 of brine can be sorbed in each room by this salt-bentonite mixture without degrading its physical integrity in the compacted state (Lappin et al., 1989, Section 4.8.1). The 40 m^3 figure comes from the amount of chemical absorption that produces a swelling pressure equal to lithostatic. The 80 m^3 figure comes from the amount of water that can be added to the bentonite-salt mixture without degrading the mixture's permeability. Neither figure takes credit for the sorptive capacity of the salt in the mixture or of the waste itself.

Potential for the formation of a slurry. It has been suggested that the accumulation of free brine in the waste disposal areas may be large enough to entrain both backfill and waste in a mobile radioactive "slurry" (Scientists Review Panel on WIPP [SRP], 1988). The SRP stated that the permeability of the Salado salt may have been underestimated and that therefore the amount of brine inflow into a waste disposal room could be about 10 times the 43 m^3 in 100 years calculated by Nowak et al. (1988). They propose that, in contact with this brine, the drums and waste will corrode to produce a slurry of dissolved and partially dissolved waste. Under the pressure of the overlying rock, this slurry would then move through any failed seals into the overlying Culebra aquifer, or up any intruding borehole to the surface.

The Environmental Evaluation Group (EEG) has reviewed the suggestion that the uncertainty regarding the quantity of brine warrants serious study (Chaturvedi et al., 1988). SRP's suggestion has also been reviewed by a committee of the National Academy of Sciences (NAS), who conclude that "the formation of an abundant mobile fluid in a repository at the WIPP site, as postulated by SRP, is very improbable." (National Research Council of the National Academy, 1988).

A slurry is a suspension of fine particles in a liquid, in which the solid constituents are easily carried along by the liquid. For a slurry to form in the waste stored at the WIPP, ample brine must be available and the waste must break down into fine particles.

The SRP postulates a tenfold greater permeability of the Salado Formation than is used in this SEIS and, therefore, a much greater brine inflow. The large values of permeability used by the SRP were from drill stem tests made by oil company techniques, and these tests are not considered by the DOE as reliable as those made for the express purpose of determining permeability at the emplacement horizon, because measurements close at hand underground with packer assemblies designed for the purpose are intrinsically better than with oil-field packers used in a low-porosity rock 1,000 or more feet down a surface-based hole. The amount of brine necessary to form a slurry is estimated to be 40 percent by volume (Lappin et al., 1989, Section 4.10.1). Room closure is expected to reduce the net room porosity to 40 percent void space within about 30 years after decommissioning, and very little brine will have entered the disposal rooms by this time. In fact, all of the brine that does enter in this time will be absorbed by the backfill.

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In addition, there are no mechanisms available to break down the backfill, waste, and waste drums into fine particulates. Rather, to quote the NAS, "most of the backfill is more likely to persist as a dense mush of salt crystals and bentonite, the waste would be in pieces, and the corroded metal would form discrete chunks" of rust. And, "release to the Culebra groundwater [also] requires that leaks in seals not only be present but large enough for passage of the particulate matter in the 'slurry', a requirement that puts additional strain on the credibility of [the slurry hypothesis]."

Finally, even if the waste were to break down into small particles and there were to be ample brine present, the flow velocities are too small to be able to transport much particulate material. It can be inferred from the initial rate of fluid flow in the Case IIC(rev) borehole (74 m^3/yr, see Table 5.65) and the diameter of the borehole (0.334 m, see Table 5.67), that the longitudinal velocity of flow up this borehole is about 3×10^{-5} m/s. If a drillbit is turning in the hole at 25 rpm (see drill logs in reports such as D'Appolonia, 1982), the circumferential velocity at the wall of the hole is about 0.4 m/s (1 mph). Only small particles would be entrained in such low-velocity flows.

For these reasons the DOE does not consider the slurry hypothesis credible and it is not included in the calculation of impacts herein. Nevertheless, the brine-inflow studies suggested by the EEG and the NAS are among those planned for the WIPP Test Phase.

Gas Generation. The gas and water contents of the disposal rooms will affect the long-term performance of the repository, especially in the event of human intrusion. Chemical reactions can produce or consume large amounts of gas and water. The air trapped in the disposal rooms at the time they are filled and sealed will consist mostly of nitrogen and oxygen. The Salado Formation will release brine and gas (primarily nitrogen), the oxygen originally trapped in the formation having been used up in various oxidation reactions. Microbial activity will oxidize cellulosic and other materials in the waste and will produce carbon dioxide (CO_2) as well as other gases, including hydrogen sulfide (H_2S), methane (CH_4), and nitrogen. The net effect of microbial activity on the amount of water in the repository, however, is unclear; drum corrosion can consume quantities of water and, in the case of anoxic (oxygen-poor) corrosion, produce hydrogen. Microbial consumption might remove hydrogen (H_2) during sulfate (SO_4^{-2}) reduction. H_2S may be removed by reaction with the iron of drums or iron corrosion products to form pyrite (FeS_2). The formation of FeS_2, however, will release the H_2 consumed during the sulfate reduction. Radiolysis of brine, cellulose, plastic, and rubber waste products will consume water and produce carbon monoxide, carbon dioxide, hydrogen, and oxygen.

These reactions are discussed in detail by Lappin et al. (1989, Appendix A). The best available review of laboratory data was used for the 1980 FEIS (Subsection 9.7.3.1; Molecke, 1979). This estimate considered four processes: bacterial degradation (the most important process), chemical corrosion, radiolysis, and thermal degradation.

The National Academy of Sciences reviewed these estimates (National Research Council, 1984), and accepted Molecke's (1979) "most probable average" estimate of 0.85 moles of gas generated per drum per year by bacterial action. This SEIS

assumes that this "best estimate" continues until 606 moles of gas per drum are produced; this takes 710 years.

In the presence of water, the waste drums can corrode to produce hydrogen by the oxidation reaction involved in rust:

$$3H_2O + 2Fe \rightarrow Fe_2O_3 + 3H_2.$$

Data reviewed by Molecke (1979) produced an estimate of the rate of production of hydrogen by corrosion of 2 moles per drum per year for 336 years (total of 672 moles). Lappin et al. (1989; Section 4.2.3 and Appendix A) extrapolated data from Haberman and Frydrych (1988) at considerably higher temperatures than expected in the WIPP to produce a much smaller estimate of 0.262 moles per drum per year for 2,000 years (total of 524 moles). This SEIS uses an average figure for corrosion-produced gas of 1.13 moles per drum per year to produce 596 moles during a period of 527 years.

In addition, the WIPP waste is projected to contain considerable quantities of metals, mostly iron. Using an estimate of 29.2 kg of iron in the drum itself and 14.6 kg of iron in the waste in each drum, Lappin et al. (1989) inferred that the hydrogen generation potential should be increased by 50 percent or 0.57 moles per drum per year for a total of 1.70 moles per drum per year of corrosion-produced gas and a total gas production of 894 moles per drum in 526 years.

Radiolysis and thermal degradation are small contributors by comparison. Estimates of their magnitudes are less than 0.05 and from 0.02 to 0.2 moles per drum per year, respectively (FEIS, Subsection 9.7.3.1).

To summarize, this SEIS uses a gas generation rate of 0.85 moles per drum per year from microbial degradation of organic materials in the waste (Molecke, 1979), resulting in a total amount of gas generated by bacterial action of 606 moles per drum. When the repository becomes saturated with brine, gas will also be produced by the corrosion (rust) of the steel drums and their iron-bearing contents. This process will generate 1.70 moles per drum per year of hydrogen and a total amount of gas produced by corrosion of 894 moles per drum (Lappin et al., 1989). These two processes combine to result in a gas generation rate of as much as 0.85 + 1.70 = 2.55 moles per drum per year and a total gas production of as much as 606 + 894 = 1,500 moles per drum.

Because of uncertainties in gas generation potentials and (especially) rates, the time during which the repository behavior will be affected by gas generation could be a great deal longer than about 500 years; it could be 10,000 years or more. The estimated rates and total potentials used in this SEIS, although uncertain, are believed to be conservative in that they maximize effects early in the repository's life. They are therefore used when needed for calculations. Better definition of gas generation under a range of possible repository conditions is a major reason for the proposed use of CH TRU waste during the Test Phase.

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Two-Phase Fluid Flow. This phrase refers to the flow of a mixture of gas and fluid, and especially flow in which the pressure of the gas drives the flow of the liquid. In the WIPP this could refer to any of three processes: 1) a gas cap could form on the Castile brine reservoir and increase the borehole brine flow, 2) inflow from the Salado Formation rock could be accompanied by gas that was in solution in that brine, and 3) gas could be generated by corrosion and by bacterial degradation of waste within the waste disposal rooms.

In the first instance, the gas cap would only develop as the intruding borehole relieves pressure on the brine and releases gas from solution. The increased flow caused by this gas would decrease radionuclide concentration input to the Culebra in Cases IIB and IID because the greater quantity of borehole brine would dilute the unchanged inflow of Salado Formation brine. In Cases IIA and IIC, the total amount of liquid injected into the Culebra would increase, but contaminant concentrations would remain the same, because for both borehole and formation brines radionuclide concentrations would be controlled by the same solubility limit.

In the second instance, the evolution of gas from the Salado Formation brine could increase the inflow of that brine into the waste storage rooms. In all four variants of Case II, this could increase the brine quantities that enter the Culebra. On the other hand, the assumption of Darcy flow may already have overestimated the rate of brine inflow.

In the third instance, with waste-generated gas occupying the residual 15 to 21 percent open space in the waste disposal rooms, the backpressure of the gas phase would tend to reduce the amount of brine inflow from the Salado Formation. However, the waste-generated gas might also tend to drive larger quantities of contaminated fluid up the intruding borehole.

Two-phase flow and transport are not treated quantitatively in this SEIS because until recently there have been no publicly available, experimentally confirmed numerical codes describing two-phase flow; all such codes were proprietary. One of the purposes of the Test Phase is to use such a code received earlier this year to investigate the implications of two-phase flow.

Radionuclide Concentrations in Brines. Recently an estimate has been made of the solubilities of certain of the transuranic elements in WIPP brines under the conditions expected for the WIPP disposal rooms (Lappin et al., 1989, Section 4.5).

Two standard brines were defined, one representing intergranular brine from the Salado Formation and one representing fluid from a brine reservoir in the Castile Formation. However, no thermodynamic data (solubility products for solid phases or stability constants for dissolved organic or inorganic complexes) were found in the literature for these elements (Am, Np, Pu, U, and Th) in solutions with ionic strengths (I) as high as those of the standard Salado and Castile brines (I = 7.66 and 6.14 M [molar], respectively); most existing data apply to solutions with I no greater than 1 M. Furthermore, most of the data are for simple metallic complexes; there are very few data for the complexes that will probably be important in these brines.

An attempt was made to estimate thermodynamic data for these elements by 1) extrapolating existing data to the ionic strengths of the WIPP brines, 2) using the data directly for the WIPP brines or arbitrarily changing them, and 3) extrapolating data for chemically analogous complexes. Unfortunately, these procedures result in order of magnitude uncertainties. In addition, influences of other processes are not yet accounted for, including microbial activity, anoxic corrosion, and the sorption of radionuclides by bentonite and iron oxides.

Laboratory experiments in the WIPP Test Phase will provide data on the solubilities and sorption of radionuclides under expected repository conditions. In lieu of such data, this SEIS uses an estimate of 10^{-6} M for the solubilities of Pu and Am, the important TRU elements in TRU waste. This is an intermediate value on a logarithmic scale of the range of values of dissolved radionuclide concentrations (10^{-3} to 10^{-9} M) that, based on solubilities in fresh water and weaker brines, have been used for sensitivity studies involving the source term.

5.4.2.5 Analysis of Scenarios: Cases IA, IB and IC. Table 5.57 briefly describes the conditions and input parameters for the cases that have been modeled. This table is provided to aid understanding of the detailed discussion that follows.

Cases IA, IB, and IC examine the expected performance of the repository when it is left undisturbed. These cases analyze the potential for radionuclide and lead migration from the repository through the various tunnels and seals and the surrounding geologic media to the external environment. The system analyzed comprises the wastes in the repository, the engineered barriers, and the surrounding geologic media, including MB139, which lies just under the disposal rooms and access tunnels.

Case IA is intended to simulate expected repository performance using the best available input parameters. This simulation represents the expected performance of the undisturbed repository without modification of existing designs of engineered barriers and waste. Case IB is intended to simulate its performance under unfavorable and unlikely conditions. Case IC is intended to simulate its performance still further degraded, with partially failed tunnel and shaft seals.

Conceptual Model of the System. After the WIPP is decommissioned, the system will consist of rooms filled with waste and backfill, but no free water will be present. New fractures will have started to form in MB139 and anhydrite "b" as a result of earlier excavation of the tunnels and rooms and in response to later salt creep into those excavations. These new fractures principally occur directly under (and over) the excavations, including in the Experimental Program area to the north of the access shafts as well as in the disposal rooms. Salt-based grout seals will be in place in MB139 directly under the panel seals. Access drifts and the Test Phase area will have been backfilled and shaft seal systems will be in place.

Gas generation in waste materials and drums will begin before the facility is finally closed and will continue after closure (Subsection 5.4.2.4). Rooms and tunnels will close, crushing the waste drums and allowing gas to fill the void volume throughout the rooms and drifts. This gas will also migrate through the fractured rock to MB139 and fill the fracture volume under previous excavations. The gas pressure will rise to lithostatic (about 14 MPa), slowing the final room closure and brine inflow and

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TABLE 5.57 Description of and input parameters for cases analyzed

Case	Description	Repository Parameters	Transport Parameter
IA	Undisturbed Performance	EXPECTED Radionuclide solubility 10^{-6} M Lead solubility in brine 116 mg/L	EXPECTED Lower shaft permeability 10^{-20} m^2 Marker Bed 139 seal permeability 4×10^{-19} m^2 Culebra permeability 5×10^{-15} to 5×10^{-13} m^2 Culebra matrix porosity 0.16
IB	Undisturbed Performance	DEGRADED Radionuclide solubility 10^{-4} M Lead solubility in brine 116 mg/L	DEGRADED Lower shaft permeability 10^{-18} m^2 Marker Bed 139 seal permeability 4×10^{-17} m^2 Culebra permeability 5×10^{-15} to 5×10^{-13} m^2 Culebra matrix porosity 0.07
IC	Undisturbed Performance	DEGRADED Radionuclide solubility 10^{-4} M Lead solubility in brine 116 mg/L	DEGRADED Lower shaft permeability 10^{-16} m^2 Marker Bed 139 seal permeability 4×10^{-16} m^2 Culebra permeability 5×10^{-15} to 5×10^{-13} m^2 Culebra matrix porosity 0.07
IIA and IIA (rev)	Response to Breach of Castile Brine Reservoir	EXPECTED Radionuclide solubility 10^{-6} M Lead solubility in brine 116 mg/L Lead solubility in Culebra 54 mg/L Waste/backfill permeability sufficient for mixing[a] Salado brine inflow 1.3 m^3/panel/year (IIA) or 1.4m^3/panel/year (IIA[rev])	EXPECTED Long-term plug permeability 10^{-12} m^2 Culebra matrix porosity 0.16 Culebra fracture porosity 0.0015 Culebra fracture spacing 2 m Culebra free-water diffusivity 1×10^{-6} cm^2/s for all radionuclides and 4×10^{-6} cm^2/s for Pb in Case IIA. Varies by radionuclide for Case IIA (rev). Culebra K_ds range from 0.1 to 200 ml/g Culebra matrix tortuosity 0.15

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TABLE 5.57 Concluded

Case	Description	Repository Parameters	Transport Parameter
IIB	Response to Breach of Castile Brine Reservoir	PERMEABILITY LIMITED SOLUBILITY DEGRADED Radionuclide solubility 10^{-4} M Lead solubility in brine 116 mg/L Lead solubility in Culebra 54 mg/L Waste precompaction reduces permeability enough to prohibit mixing[b] Salado brine inflow 1.3 m^3/panel/year	DEGRADED Long-term plug permeability 10^{-11} m^2 Culebra matrix porosity 0.07 Culebra fracture porosity 0.0015 Culebra fracture spacing 7 m Culebra free-water diffusivity 5 x 10^{-7} cm^2/s for all radionuclides and 2 x 10^{-6} cm^2/s for Pb Culebra K_ds range from 0.05 to 100 ml/g Culebra matrix tortuosity 0.03
IIC and IIC (rev)	Response to Breach of Castile Brine Reservoir	DEGRADED Radionuclide solubility 10^{-4} M Waste/backfill permeability sufficient for mixing[a] Salado brine inflow 1.3 m^3/panel/year (IIC) or 1.4m^3/panel/year (IIC[rev])	DEGRADED Long-term plug permeability 10^{-11} m^2 Culebra matrix porosity 0.07 Culebra fracture porosity 0.0015 Culebra fracture spacing 7 m Culebra free-water diffusivity 5 x 10^{-7} cm^2/s for all radionuclides, 2 x 10^{-6} cm^2/s for Pb in Case IIC. Varies by radionuclide for Case IIC (rev) Culebra K_ds range from 0.05 to 100 ml/g Culebra matrix tortuosity 0.03
IID	Response to Breach of Castile Brine Reservoir	PERMEABILITY LIMITED SOLUBILITY AS EXPECTED Radionuclide solubility 10^{-6} M Waste/backfill permeability prohibits mixing[b] Salado brine inflow 0.1 m^3/room/year	DEGRADED Long-term plug permeability 10^{-11} m^2 Culebra matrix porosity 0.07 Culebra fracture porosity 0.0015 Culebra fracture spacing 7 m Culebra free-water diffusivity 5 x 10^{-7} cm^2/s for all radionuclides and 2 x 10^{-6} cm^2/s for Pb Culebra K_ds range from 0.05 to 100 ml/g Culebra matrix tortuosity 0.03

[a] Sufficient for mixing = it is assumed that Castile brine equilibrate to same radionuclide and lead concentration as in repository at each time step.

[b] Because of elimination of brine mixing, only long-term source of radionuclides and lead is from Salado brine flow through waste/backfill.

maintaining open fractures in MB139. Gas generation is assumed to continue for 2,000 years or more. As gas generation slows and pressures drop below lithostatic, brine will begin to resaturate the facility and MB139.

All versions of Case I assume that the 2,000-year gas generation phase passes without untoward effects, the gas finding its way out, either through MB139 and the shaft seals or into fractures in the surrounding salt, and that the facility promptly resaturates (Subsection 5.4.2.3). Case I starts after the rooms are fully resaturated with brine, now under full lithostatic pressure and saturated with dissolved radionuclides and lead.

Figure 5.4 shows the repository system for Case I. The preferred path for radionuclide and lead release is from the waste rooms into MB139 and around and through the seal in MB139 under the room seal to the base of the shafts. The transport then continues through the lower and upper shaft seals to the Culebra aquifer in the Rustler Formation. The lower seal has been well consolidated by salt creep and closure about the shaft, while the upper seal is not as well consolidated. Radionuclide and lead transport will then follow a path within the Culebra aquifer to the stock well location. Although the pathway just described is a preferred path in that each leg of the pathway has a higher permeability than the host rock, a flow path from the facility through the host rock directly toward the Culebra aquifer also must be considered because of the large cross-sectional area of the facility. This direct route is in parallel with the path through MB139 and the shaft seals.

Computer Model and Inputs. The NEtwork Flow and TRANsport code (NEFTRAN) was developed for the Nuclear Regulatory Commission to simulate groundwater flow and radionuclide transport in an efficient manner (Longsine et al., 1987). NEFTRAN assumes that significant flow and radionuclide and lead transport take place along discrete one-dimensional legs or paths. These legs are assembled into a network representing the flow field. NEFTRAN requires pressure boundary conditions to solve the flow equations, and these conditions must be specified as part of the input (Appendix I.1.1). These boundary conditions as well as the flow network can be defined from detailed flow fields predicted by flow models such as SWIFT II (the Sandia Waste Isolation, Flow, and Transport code) (Reeves et al., 1986a and 1986b; see also Subsection 5.4.2.6).

NEFTRAN has the ability to handle a generalized network, which the user sets up by specifying the number of legs through which flow will be calculated, and the junctions at the end of each leg. The user also determines the junctions where boundary conditions are specified. The underlying assumption is conservation of mass and flow at each junction. NEFTRAN first solves the pressures at the junctions and then calculates the volume and flow rate in each leg using Darcy's Law. From these calculations, the average fluid velocity on its tortuous path through each leg is calculated. In NEFTRAN, each radionuclide species and lead can have a different retardation factor in each leg of the migration path, and the average species velocity for each leg is treated separately. NEFTRAN uses a mean velocity for each radionuclide species and lead. It simulates the flow by keeping track of how a group of representative particles moves through each leg of the network. By this means it is able to allow for convective-dispersive transport, transport which accounts both for flow with the water and for dispersion along the path of flow. NEFTRAN can treat radionuclide chains of arbitrary length and retardation; it does introduce some numerical dispersion, but this can be controlled (Campbell et al., 1981).

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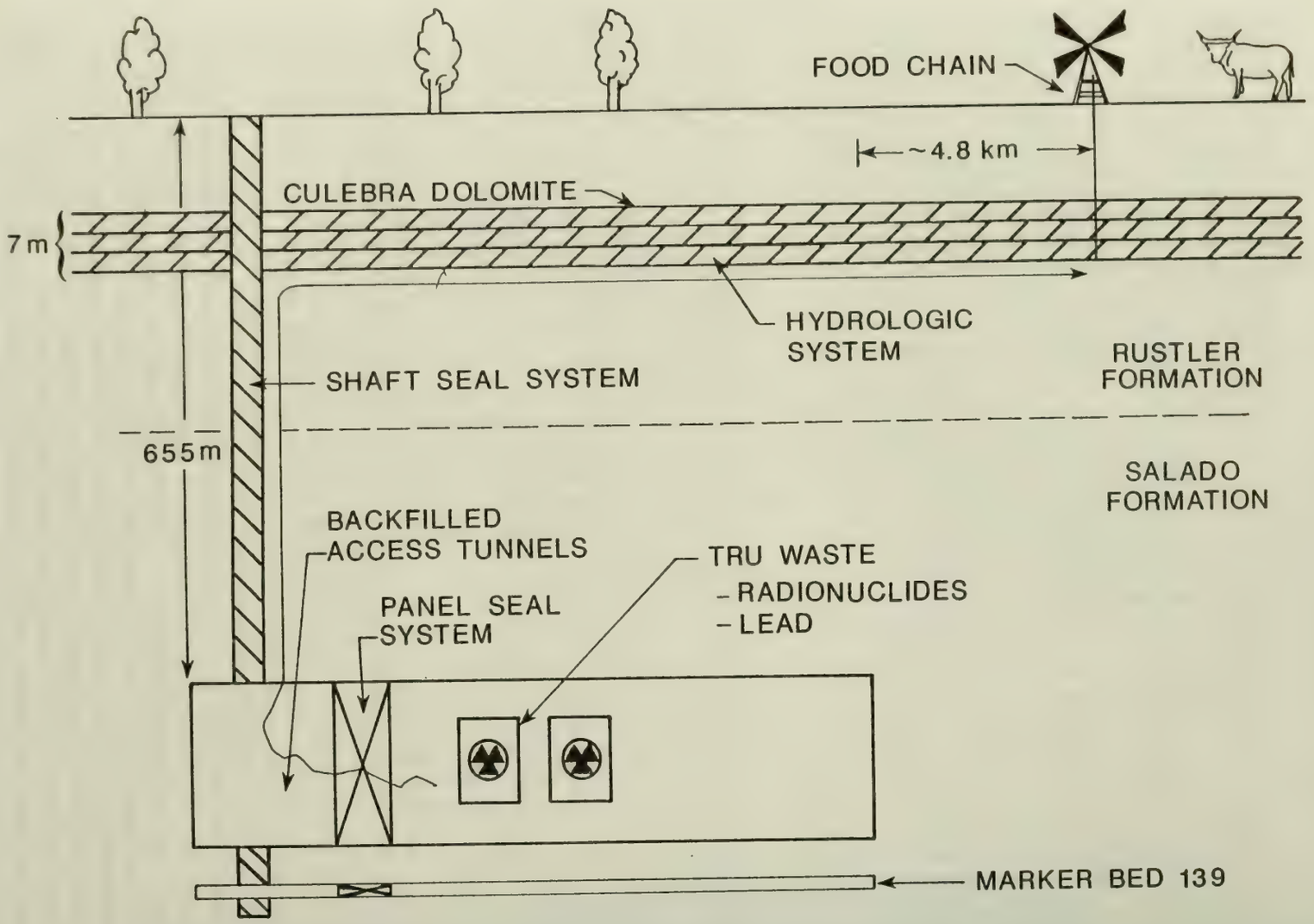


REF: LAPPIN et al., 1989.

FIGURE 5.4

SCHEMATIC OF THE REPOSITORY FOR CASE I, UNDISTURBED PERFORMANCE

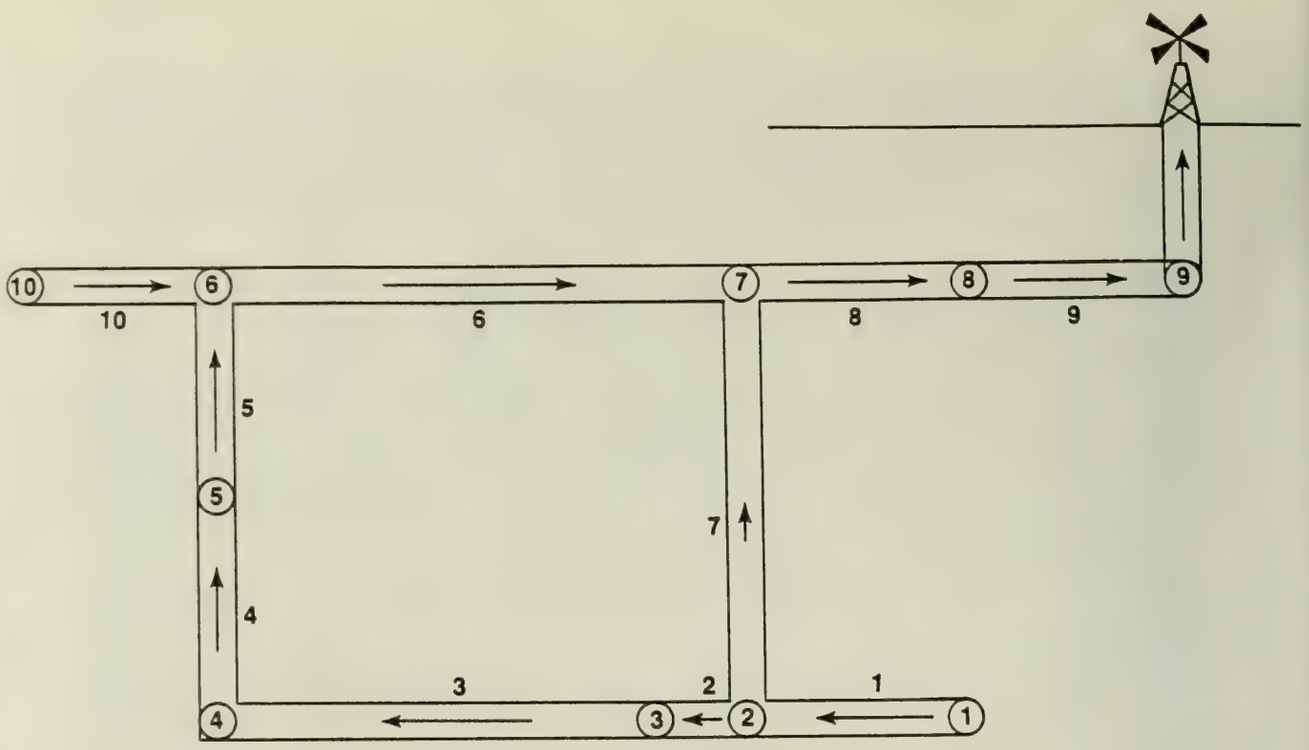
Generalized Network for the Undisturbed Repository. A generalized flow network for Cases IA, IB, and IC is shown in Figure 5.5. Arrows indicate flow direction along each leg. Uncircled numbers are the legs. Circled numbers are nodes between legs. Legs 1 and 10 are included to establish continuous flow in the network for MB139 and the Culebra aquifer of the Rustler Formation, respectively.

The path consisting of Legs 1, 2, and 3 represents flow through MB139. Leg 2 represents the grouted seal in the marker bed that underlies the panel seal. Leg 3 represents the direct path through MB139 from that seal to the bottom of the shafts. It is assumed that this path underlies only the excavated spaces, not the pillars between them. Leg 4 represents the consolidated lower shaft seals from the repository depth up the shaft about 200 m. This leg represents the waste shaft that has the largest diameter of the four shafts. Leg 5 simulates the poorly consolidated upper shaft seal system. Legs 6, 8, and 9 simulate the path through the Culebra aquifer to the WIPP boundary at Node 8 and to the stock well location at Node 9. The hydraulic conductivities used in Legs 6 through 9 are the same as those used by LaVenue et al. (1988), and in the analysis of SEIS Subsection 5.4.2.6 below. This path was used for Cases IA, IB, and IC. Leg 7 represents a flow path directly from the panel to the Culebra aquifer through the Salado. The cross-sectional area of Leg 7 is the total floor area of the rooms and tunnels that contain waste. A second NEFTRAN run was made to calculate transport along this path and thence to the stock well along Legs 8 and 9.

The transport parameters used for these calculations are listed in Tables 5.58 and 5.59. The degraded transport parameters in Case IB are comparable to those used in Subsection 5.4.2.6 below for Cases IIB, IIC, IIC(rev) and IID. Case IB is degraded from Case IA by an increased radionuclide solubility, an increased permeability in the MB139 and lower shaft seals, and a decreased porosity and other changes in the Culebra aquifer. For Case IC the permeability of the MB139 seal is increased by another factor of 10 and that of the lower shaft seal by another factor of 100. Thus the permeabilities of these seals are taken to be higher by factors of 3×10^4 to 10^5 than those of the host rock (3×10^{-21} m^2, see Lappin et al., 1989, Table 3-1).

Time Calculations. Transport calculations for radionuclides and lead were performed for the path described from Node 2 to Node 9 via Nodes 3, 4, 5, 6, 7, and 8. The arrival times for lead and the least retarded radionuclides (the uranium nuclides) were so long that separate calculations were made for arrival times at intermediate nodes (Table 5.60). These arrival times for the least retarded radionuclides and lead to the Culebra aquifer were based on the first arrival of reasonably detectable activities or concentration. The threshold activity used for radionuclides was 10^{-10} Ci/day (increased from 10^{-18}Ci/day in the draft SEIS) and the threshold concentration used for lead was 8×10^{-9} g/day.

These thresholds are consistent with health-based thresholds. The Annual Limit of Intake (ALI) for uranium-233, the earliest arriving radionuclide in Case I, is 4×10^5 Bq/yr (ICRP, 1979, p 104) or 3×10^{-8} Ci/day, consistent with the figure of 10^{-10} Ci/day chosen for a threshold level of radionuclides, in that the latter figure is comfortably lower. The proposed drinking water standard for uranium is 30 pCi/L (40 CFR Part 192, 52 FR 36007, Sept. 24, 1987), or, with a liquid intake of 2 L/day, 60 pCi/day, or 0.6×10^{-10} Ci/day, again of the same order of magnitude as the chosen threshold.



NOT TO SCALE

REF: LAPPIN et al., 1989.

NOTE: NODE 2 IS THE BOUNDARY BETWEEN THE WASTE PANEL AND MARKER BED 139. NODE 3 IS THE END OF THE MARKER BED 139 SEAL. NODE 4 IS THE BOTTOM OF THE SHAFT; NODE 5 IS THE TOP OF RECONSOLIDATED SALT IN THE SHAFT; AND NODE 6 IS THE TOP OF THE SHAFT IN THE CULEBRA DOLOMITE. NODES 10, 6, 7, 8, AND 9 SEPARATE PORTIONS OF CULEBRA DOLOMITE WITH SLIGHTLY DIFFERENT HYDROLOGIC PROPERTIES. NODE 9 IS THE HYPOTHETICAL STOCK WELL. NODES 1 AND 10 ARE INPUT NODES IN THE REPOSITORY AND CULEBRA DOLOMITE.

FIGURE 5.5
NUMERICAL FLOW NETWORK INPUT FOR SIMULATION OF CASES 1A, 1B, AND 1C

TABLE 5.58 Numerical parameters input to NEFTRAN for Cases IA, IB, and IC

	Permeability (m^2)			Porosity			
	IA	IB	IC	IA	IB and IC	Length of path (m)	Cross-sectional area of path (m^2)
MB139 Seal (Leg 2)	4×10^{-19}	4×10^{-17}	4×10^{-16}	0.03	0.03	30	0.76
MB139 (Leg 3)	3×10^{-7}[a]	3×10^{-7}[a]	3×10^{-7}[a]	1.00[a]	1.00[a]	366	0.76
Lower Shaft (Leg 4)	10^{-20}	10^{-18}	10^{-16}	0.05	0.05	200	29.2
Upper Shaft (Leg 5)	10^{-12}	10^{-12}	10^{-12}	0.20	0.20	200	29.2
Culebra (Leg 6)	5×10^{-15}	5×10^{-15}	5×10^{-15}	0.16	0.07	430	800
Culebra (Leg 8)	5×10^{-14}	5×10^{-14}	5×10^{-14}	0.16	0.07	1030	800
Culebra (Leg 9)	5×10^{-13}	5×10^{-13}	5×10^{-13}	0.16	0.07	3450	800
Salado host rock (Leg 7)	3×10^{-21}	3×10^{-21}	3×10^{-21}	0.001	0.001	400	8030
Dispersivity (m)	15.2	15.2	15.2				
Solubility limit of radionuclides (M)	10^{-6}	10^{-4}	10^{-4}				
Pressure at Repository (MPa)	14.8	14.8	14.8				
Pressure at Culebra (MPa)	1.0	1.0	1.0				
Brine concentration							
In the Culebra - half saturated							
Below the Culebra - saturated							

[a] An effective hydraulic conductivity was derived for the fractures in MB139 using $K = b^2 \rho g / 12\mu$ with b = fracture aperture, ρ = fluid density, and μ = fluid viscosity. A fracture aperture of 2 mm was used, and to be consistent with the treatment of flow through fractures in NEFTRAN, a porosity of 1.0 was used.

Source: Lappin et al., 1989, Tables D-2 and D-3; Lappin et al., 1990, to be published.

TABLE 5.59 Numerical retardation factors input to NEFTRAN for use in Cases IA, IB, and IC

Path	Retardation Factor	
MB139 Seal	1	For all radionuclides and lead
MB139	4.7	Pu, Th
	1.93	Am
	1.04	U, Np, Ra, Pb
Lower shaft	5.16	Pu, Am, Th
	1.42	Np
	1.04	U, Ra, Pb
Upper shaft	1.74	Pu, Am, Th
	1.07	Np
	1.007	U, Ra, Pb
Salado host rock	231	Pu, Am, Th
	240	Np
	3.3	U, Ra, Pb
Culebra (Case IA)	1500	Pu, Th
	3000	Am
	16	U, Np, Pb, Ra
Culebra (Cases IB and IC)	3800	Pu, Th
	7600	Am
	39	U, Np, Pb, Ra

Source: Lappin et al., 1989, Table D-4.

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TABLE 5.60 Arrival times at intermediate points between the waste disposal rooms and the stock well (years)

	To bottom of shaft (Node 4)	To top of lower shaft seal (Node 5)	To the Culebra aquifer (Node 6)	To the stock well (Node 9)
Case IA				
(radionuclides)	500,000	1,300,000	4,800,000	>4,800,000
(lead)	nr	nr	3,500,000	5,100,000
Case IB				
(radionuclides)	3,500	8,500	27,000	240,000
(lead)	nr	nr	28,500	250,000
Case IC				
(radionuclide)	27	200	400	220,000
(lead)	nr	nr	400	200,000
Direct route (Leg 7)	na	na	400,000	>400,000

Note: nr = not reported, na = not applicable

Source: Lappin et al., 1990.

Similarly, a suggested safe level for stable lead in drinking water is 0.05 ppm (40 CFR 141), or 5×10^{-5} g/L, at a liquid intake of 2 L/day, 10^{-4} g/day. The stable-lead threshold used in the calculation of 8×10^{-9} g/day is well below that.

In Case IA, the least retarded radionuclides (the uranium nuclides) were found to travel less than 10 m beyond the seal in MB139 in 10,000 years. Many millions of years are required for these radionuclides to reach the Culebra. In Case IB, those radionuclides travel less than 20 m above the lower shaft seal. In Case IC, those radionuclides reach the site boundary in 180,000 years and the stock well in 220,000 years. Stable lead arrival times were about the same. (Case IA is essentially the same long-term release scenario as the one in the No-Migration Variance Petition [DOE, 1989c].)

The differences in arrival times for radionuclides and stable lead arise from two factors. First, the half-life of the first-arriving radionuclide, uranium-233, is 160,000 years, much smaller than the 4,800,000 year arrival time at the Culebra, whereas stable lead has an infinite half-life. Thus, this uranium appears to have traveled for 30 half-lives. Actually, it has been continually replenished by its relatively long-lived (2,100,000 years) and slower-traveling parent Np-237. This has had the effect of slowing its apparent

transport velocity. This accounts for stable lead arriving at the Culebra in Case IA in 3.5 million years, well before uranium-233, which takes 4.8 million years to reach that point. Then too, the time steps used in these calculations were from 500 to 10,000 years, depending on how far along the calculation had thus far extended. Small differences in the calculational approximations to radionuclide behavior, therefore, can make differences such as that between the 27,000-year and the 28,500-year arrival times at the Culebra in Case IB.

Calculations were also made for transport through the host rock to the Culebra aquifer (Leg 7). (For this route all three cases are the same.) The arrival time for the least retarded radionuclides at the Culebra aquifer was estimated to be 400,000 years; and at 10,000 years, no radionuclide has traveled farther than about 10 m in the host rock. 400,000 years is a much shorter travel time than the 4,800,000 years calculated in Case IA. This counter-intuitive result comes from the use of Darcy's law. According to that law, travel times are proportional to porosity and inversely proportional to permeability. Thus, the much lower porosity in the salt (rather than in the seals) and the nearly equal permeability, combine to predict an earlier arrival time at the aquifer. This occurs because the movement is through the rock mass, rather than through the expected path of the shaft and tunnels.

Based on these calculations for representative and degraded conditions in Cases IA and IB, there are no releases of radionuclides or lead to the Culebra for well over 10,000 years, and, therefore, none to the hypothetical stock well.

In the extreme conditions assumed in Case IC, on the other hand, radionuclides reach the aquifer in 400 years but then travel very slowly and do not reach the stock well until well after 10,000 years. Therefore, there are no integrated releases or human exposures during this time. Radioactivity and lead are not available for transport through the biosphere to humans in any of these three cases.

5.4.2.6 Analysis of Scenarios: Cases IIA, IIA(rev), IIB, IIC, IIC(rev), and IID. The possible exposure pathways for these cases start with the release of material to the surface at the top of the intruding well. Four kinds of releases are possible: 1) the drill head penetrates a repository panel and removes cuttings; 2) particles are eroded from the consolidated waste by the circulating drilling mud and entrained Castile brine; 3) some Salado brine enters the borehole to be carried to the surface; and 4) there may be a release of radon gas when the drill bit penetrates a repository room.

The numerical implementation below of the coupling of the brine reservoir and the Culebra dolomite assumes that, once the borehole plugs degrade, all flow enters the Culebra and no fluid is released to the ground surface. This is justified by the fact that the maximum pressure build-up values simulated at the borehole location in the Culebra dolomite are <0.02 MPa for both Cases IIA(rev) and IIC(rev). This pressure increase, which is small relative to the 1.5-MPa pressure increase at Culebra depth that would be required to drive brine to the surface, confirms that there would be no direct flow to the ground surface for the brine reservoir, Culebra, and borehole properties used in the Case II simulations.

It is indicated in Subsection 5.4.2.3 that there will be an ingrowth of radon into the waste, amounting at 10,000 years to 120 Ci total, or 1.2 Ci in each of the roughly 100 equivalent disposal rooms. After a few hundred years, the gases in the disposal rooms will be under pressure, and when the intruding drill hole reaches the repository, these gases and the intermixed radon will start up the 2000-ft column of drilling mud. Realistically, not all the radon will be free to move immediately. Some of it will be dissolved in the brine in the disposal rooms and some will be trapped in the individual waste particles with its radium parent; only the remainder will be in the remaining open void space free to move, and much of this will be in the interstices between waste grains. Thus the radon-bearing gases will pass into the mud in the drill hole over a period of several minutes and in passing upward through the mud, part of the gas will be dissolved and the rest will be broken up into a stream of bubbles. The initial gaseous release will be followed by a lesser rate of gas, and all this gas will dissipate quickly in the air at the surface.

Thus no individual at the surface will breathe an appreciable fraction of the radon gas from the disposal rooms. Finally, the radon that comes to the surface dissolved in the brine and drilling fluid will be discharged to the mud pit and, with its 3.8-day half-life, decay before it can affect either the drill crew or the downwind ranch family appreciably.

In calculating the radiation doses from the cuttings brought to the surface, the eroded drill hole diameter was assumed to be the same in all four cases. No allowance was made for the fact that the compacted waste in Cases IIB and IID will be more resistant to erosion than that in Cases IIA and IIC.

Drilling practices used in the Delaware Basin are described in Lappin et al. (1989, Appendix C). A hole, assumed to be 13-1/8 (33.4 cm) inches in diameter would be drilled to the Rustler, then cased. When the hole reaches the brine reservoir in the Castile Formation, there would be a show of gas or brine in the drilling mud. The drilling crew would stop this outflow with a blowout preventer, then add weight to the drilling mud (probably by adding barite) to control this flow. In the process little brine would be released as such at the surface. Nevertheless, it was assumed that during the 80 hours needed to drill from the Castile brine reservoir down to oil presumed to be in the underlying Bell Canyon Formation, the circulating mud would bring up to the surface 1,000 barrels of brine from the Castile reservoir, some waste eroded from the repository, and some Salado Formation brine.

A cylindrical volume of waste was assumed to be brought to the surface out of the repository. Its diameter was estimated as the 33.4-cm diameter of the drill bit plus a calculated 10-cm additional erosion around for a total diameter of 53.4 cm. Its height was 107 cm, this being the expected thickness of the repository after closure. This net volume of 240 liters is equivalent to almost 3 compacted drums.

Eighty hours of Salado Formation brine inflow at 1.3 m^3/yr is 12 liters and, for a radionuclide solubility of 10^{-4} molar (Cases IIB and IIC), this Salado brine will carry with it the equivalent of about 1/30 drum of radionuclides. For Cases IIA and IID, the quantity of radionuclides will be much less, the solubility being only 1/100 as great.

This material would be discharged into a settling pond (also called a mud pit) at the surface adjacent to the well. While members of the drill crew could be exposed externally to this material, the principal exposure would be to a geologist who examines the drill cuttings.

The same approach as that used in the FEIS (Subsection 9.7.1.5) was used to estimate the external dose to the geologist. Assuming that the geologist examines a cuttings sample for 1 hour from a distance of 1 m, the exposure was calculated as if the sample is a point source that is not self-shielded. The estimated doses are given in Table 5.61, assuming drilling is directly through a compressed drum of CH TRU waste and a cuttings sample size of 526 cm^3. For drilling through an RH TRU canister at 100 years after the repository is decommissioned and closed, the exposure would be as given in Table 5.62.

The radiation exposure rate from natural background in the United States is about 100 mrem/year, or 0.01 mrem/hour. The background is somewhat higher at the WIPP site, where the altitude is about 3,000 ft. The exposure rate from CH TRU waste of 0.077 mrem/hour to the geologist is eight times background, but the exposure only lasts 1 hour. However, if the drill bit intercepted RH TRU waste, his/her exposure rate would be much greater, 91 mrem/hour. The geologist would receive a dose of 91 mrem. Background being about 100 mrem/year, this exposure would almost double the geologist's exposure that year. One notes, however, that almost all this radiation dose is from the Cs-137 in the cuttings sample, and that in only 180 more years, its contribution would decay to 1.4 mrem giving a total radiation dose of 2.8 mrem. After that time, its contribution would be less than the contribution of the next biggest contributor to the total dose, Am-241.

TABLE 5.61 Maximum dose received by a drilling crew member due to exposure to CH TRU waste-contaminated drilling cuttings

Nuclide	Activity/sample (mCi)	Energy/gamma (MeV)	n (γq/dis)[a]	Exposure (mrem/hr)
Pu-238	35	0.099	8.0×10^{-5}	1.4×10^{-4}
Pu-239	4	(no gamma)		
Pu-240	1	0.65	2.0×10^{-7}	6.5×10^{-8}
U-233	0.06	0.029	1.7×10^{-4}	1.5×10^{-7}
U-235	3.2×10^{-6}	0.14-0.20	0.05-0.54	3.0×10^{-7}
Am-241	7.1	0.06	0.36	0.077
Np-237	7.3×10^{-5}	(no gamma)		
Total				0.077

[a] γq/dis = gamma quanta per disintegration.
Source: Lappin et al. (1989) Table 7.2.

TABLE 5.62 Maximum dose received by a drilling crew member due to exposure to RH TRU waste-contaminated drilling cuttings at 100 years after repository closure

Nuclide	Activity/sample (mCi)	Energy/gamma (MeV)	n (γq/dis)[a]	Exposure (mrem/hr)
Sr-90	340	(no gamma)		
Cs-137	320	0.66	0.85	90
Pu-238	1950	0.099	8.0×10^{-5}	7.7×10^{-3}
Pu-239	5050	(no gamma)		
Pu-240	740	0.65	2.0×10^{-7}	4.8×10^{-5}
Pu-241	74	0.16	6.7×10^{-8}	4.0×10^{-7}
Am-241	130	0.06	3.6×10^{-1}	1.40
Total				91

[a] γq/dis = gamma quanta per disintegration.

After drilling operations cease, radioactive material remaining in the settling pond would become available for transport through airborne or surface-water pathways. Doses to a ranch family hypothesized to live 500 m downwind from the settling pond were assessed in the FEIS, (Subsections 9.7.1.6 and K.3.1). The calculation was conservative, because most lands in this region are desert lands not suitable for farming. However, the dose estimates are repeated for completeness.

The pathways that result in radiation doses to the hypothetical ranch family begin with the transport of respirable particles from the settling pond by wind erosion. Surface water was not considered a viable transport mode in the FEIS, because there is no surface runoff from the site, and it is not considered in this analysis. The pathways are the same as those considered in the FEIS. They include:

- Inhalation of contaminated air
- Ingestion of foods (meat, milk, and above- and below-surface food crops) produced on the ranch.

The estimated committed doses to individual members of this family are given in Tables 5.63 and 5.64. These are the radiation doses that an individual person would receive during the next 50 years as a result of a 1-year exposure. The principal exposure is from inhalation. Table 5.63 represents a drillhole passing through a CH TRU waste storage room, and Table 5.64 represents a drillhole passing through an RH

TABLE 5.63 Committed effective dose equivalent after 1-year exposure (mrem during the subsequent 50 years)

CH TRU waste

Nuclide	Beef	Milk	Above-surface Crops	Below-surface Crops	Inhalation[a]
Am-241	2.76×10^{-8}	9.06×10^{-7}	8.01×10^{-7}	9.36×10^{-7}	2.62×10^{-1}
Np-237	7.48×10^{-13}	4.42×10^{-12}	3.82×10^{-9}	nc	2.58×10^{-6}
Pu-238	1.54×10^{-10}	2.45×10^{-12}	3.00×10^{-7}	1.23×10^{-6}	4.37×10^{-1}
Pu-239	1.80×10^{-11}	2.86×10^{-13}	3.52×10^{-8}	1.44×10^{-7}	5.40×10^{-2}
Pu-240	4.49×10^{-12}	7.17×10^{-14}	8.80×10^{-9}	3.59×10^{-8}	1.35×10^{-2}
U-233	5.34×10^{-11}	5.66×10^{-10}	1.45×10^{-9}	6.63×10^{-10}	2.62×10^{-4}
U-235	2.66×10^{-15}	2.83×10^{-14}	7.23×10^{-14}	3.32×10^{-14}	1.19×10^{-8}
Total ingested dose:			4.43×10^{-6}		
Total inhaled dose:					7.66×10^{-1}

[a] Assumes a breathing rate of 2.7×10^{-4} m^3/s
[b] nc = not calculated

Source: Corrected from Lappin et al. (1989), Table 7.8.

TABLE 5.64 Committed effective dose equivalent after 1-year exposure (mrem during the subsequent 50 years)

RH TRU waste

Nuclide	Beef	Milk	Above-surface Crops	Below-surface Crops	Inhalation[a]
Sr-90	6.76×10^{-8}	6.90×10^{-7}	2.30×10^{-5}	2.51×10^{-6}	3.94×10^{-5}
Cs-137	2.55×10^{-8}	5.35×10^{-7}	9.16×10^{-7}	6.79×10^{-7}	3.43×10^{-7}
Pu-238	2.41×10^{-11}	3.84×10^{-10}	4.57×10^{-8}	1.92×10^{-7}	6.77×10^{-2}
Pu-239	6.80×10^{-11}	1.08×10^{-9}	1.29×10^{-7}	5.43×10^{-7}	2.05×10^{-1}
Pu-240	2.18×10^{-11}	3.48×10^{-10}	4.15×10^{-8}	1.74×10^{-7}	6.58×10^{-2}
Pu-241	1.44×10^{-12}	2.29×10^{-11}	2.73×10^{-9}	1.15×10^{-8}	6.47×10^{-5}
Am-241	4.42×10^{-9}	1.49×10^{-8}	1.28×10^{-7}	1.49×10^{-7}	4.19×10^{-2}
Total ingested dose:			2.99×10^{-5}		
Total inhaled dose:					3.81×10^{-1}

[a] Assumes a breathing rate of 2.7×10^{-4} m^3/s

TRU waste canister. Therefore, this person would receive 0.015 mrem/year from CH TRU waste (0.0076 mrem/year from RH TRU waste) on the average or 0.015 percent (0.008 percent) of his/her annual background exposure. Over the next 50 years, his/her body burden would build up, so that in his/her 50th year, the individual would receive an exposure of 0.77 mrem (or 0.38 mrem from RH TRU waste). (Note: one of the contributors to the RH TRU waste exposure is Cs-137. Not being a bone seeker as Sr-90 and the transuranics are, it does not build up in the body for 50 years, but its contribution is such a minor part of the total, that the net conclusion is not changed.)

Similarly, the calculated concentration of lead in the ambient air at the hypothetical ranch is 5.16×10^{-12} mg/m^3, and the ground surface deposition is 1.63×10^{-9} g/m^2 (Appendix I.1.4). Assuming a 70-kg man breathing 20 m^3/day (EPA, 1986), and that 35 percent of this material is absorbed into the body (ATSDR, 1988), his daily intake of lead is 5.16×10^{-13} mg/kg-day.

The estimate of the daily intake of lead by humans calculated in this manner can be compared to the level for chronic intake (AIC) described in the Superfund Public Health Evaluation Manual (EPA, 1986). The AIC level for lead is 4.3×10^{-4} mg/kg-day. The calculated AIC-based hazard index for lead is therefore $5.16 \times 10^{-13}/4.3 \times 10^{-4} = 1.2 \times 10^{-9}$. This value is well below one, indicating that the intake of stable lead by inhalation is well below the level of chronic intake. The dose calculated for inhalation is the most direct, and therefore the highest pathway for lead intake. Because of the small quantity of lead deposited on the ground surface, and the even smaller amounts potentially taken up by animals and plants, it can be safely assumed that all other potential pathways in this scenario (i.e., ingestion of vegetables, milk, and meat) will be orders of magnitude below inhalation-based levels.

Post-Plugging Analysis: Models and Codes. In the analysis of the various variants of Case II, the SWIFT II model was used to 1) simulate the release of fluid from a hypothetical brine reservoir connected via a borehole through the repository to the Culebra aquifer, 2) simulate the flow field within the Culebra aquifer, and 3) simulate transport of contaminants in the fractured Culebra dolomite. SWIFT II is a fully transient, three-dimensional code that solves the coupled equations for transport in geologic media. The processes considered in this application are:

- Dual-porosity fluid flow, accounting for matrix porosity and fracture flow
- Movement of a dominant solute (salts)
- Trace-species movement (radionuclide chains and stable lead).

SWIFT II has been in continuous development and upgrading since 1975 and is supported by comprehensive documentation and an extensive testing history (Reeves et al., 1986a,b). It is one of the most extensively verified codes in current use for the analysis of radioactive-waste transport in groundwater.

Figure 5.6 indicates the main features of a brine-reservoir breach. It shows a borehole that passes through the repository and connects a brine reservoir to the Culebra

aquifer. LaVenue et al. (1988) describe in detail the most recently published model of flow in the Culebra aquifer; they used the SWIFT II code to calibrate the steady-state model of regional flow within the aquifer. The analyses summarized here for Cases IIA, IIB, IIC, and IID used that model, combining the pressurized brine reservoir analytically as a source term. This model has been updated since the draft SEIS, and the analyses for Cases IIA(rev) and IIC(rev) use the updated model.

The brine reservoir is idealized as a porous disk whose properties vary with distance from its center. The flow would be radially inward to the bottom of a borehole, then upward. The inward flow causes a pressure drawdown in the reservoir that, together with the flow itself, must be matched to the pressure and flow in the borehole.

As the brine passes the waste repository, it would pick up a burden of dissolved radionuclides and stable lead. For Cases IIA and IIA(rev), the hydraulic conductivity of the waste panel (1×10^{-6} m/s) was assumed to be high enough for the Castile brine to pick up its full burden of waste radionuclides and stable lead before continuing up the borehole.

This circulation was assumed to be limited to a single waste panel that contains seven rooms and two long access tunnels filled with waste and backfill. During this circulation, the brine would dissolve waste to a solubility limit of 1×10^{-6} molar for the radionuclide constituents and 116 mg/L for stable lead, if available. Brine inflow from the Salado Formation would provide a second, smaller source of fluid that would move through the repository and bring dissolved waste radionuclides into the borehole flow. The long-term brine inflow rate from the Salado has been conservatively estimated at 1.4 m^3 per year for a single waste panel.

For Case IIB, compacting the waste and backfilling the remaining void volume would reduce the hydraulic conductivity of the waste panel to 1×10^{-11} m/s. It was assumed that in this case the Castile brine could no longer circulate through the waste and dissolve radionuclides and lead. The only remaining source of contaminated fluid entering the borehole would thus be brine inflow from the Salado Formation (Table 5.57). Radionuclide solubility was increased by a factor of 100, to 10^{-4} molar.

Case IIB assumed the same brine inflow rate (1.3 m^3 per year per panel) that was used in Case IIA. This rate is conservative since no credit was taken for the reduced hydraulic conductivity causing a reduction in the brine inflow rate. Case IIB also assumed degraded groundwater transport in the borehole and in the Culebra.

Cases IIC and IIC(rev) are similar to Case IIB, except that these cases assumed that the waste is not precompacted and that the Castile brine could flow freely through the repository.

Case IID incorporated a degraded groundwater transport projection (the same as in Cases IIB, IIC, and IIC[rev]), expected values for radionuclide solubility (same as Case IIA and IIA[rev] values), assumed pretreatment of the waste and backfill that eliminated Castile brine flow through the repository, assumed a source term limited to a single room instead of an entire panel, and reduced Salado brine inflow rates (0.1 m^3/yr).

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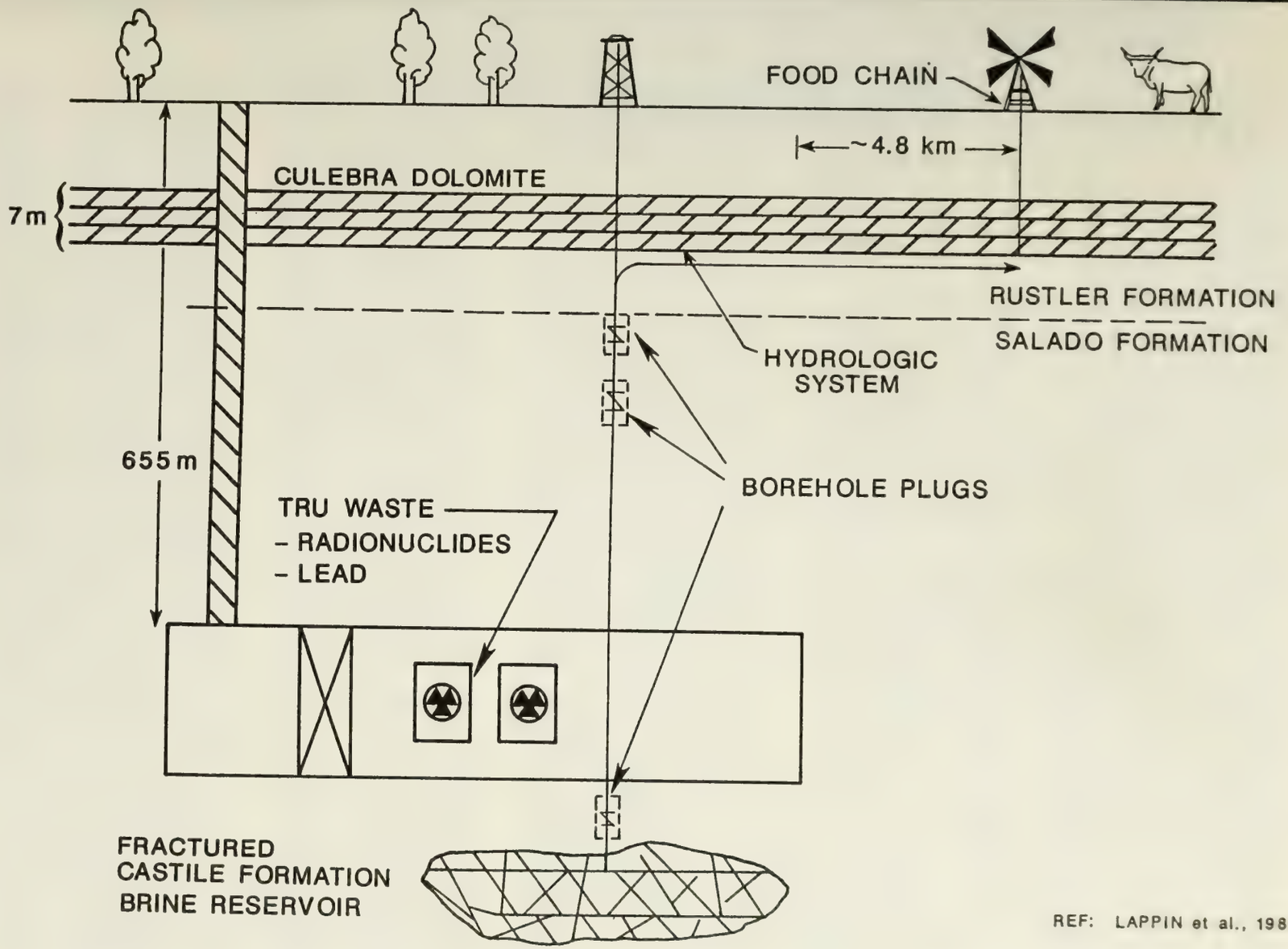


FIGURE 5.6
SCHEMATIC OF THE REPOSITORY AND UNDERLYING CASTILE FORMATION BRINE RESERVOIR FOR CASE II, PERFORMANCE WHEN DISTURBED BY HUMAN INTRUSION

Two more assumptions in these repository source terms are to be noted. First, the characterization of waste transport solely as dissolved species assumed that colloid formation and transport and particulate transport were minor. Second, Case II assumed that waste-generated gas would vent from the room when drilling intercepted the repository. Given that this scenario involved just one drill hole in an entire waste panel, it is possible that the system might behave in a more heterogeneous manner, with the gas produced in more distant parts of the panel helping to drive fluid up the borehole. This process, however, cannot be evaluated in a quantitative fashion at the present time (Subsection 5.4.2.4).

Flow Calculations. The Case II simulations presented in the draft SEIS used a one-dimensional stream-tube approach for calculating the transport of contaminants in the Culebra. The revised Case II transport calculations presented here use a two-dimensional system to meet two objectives: 1) to provide more accurate estimates of breakthrough-curve concentrations for the contaminants at the stock well that incorporate lateral-dispersion and species-specific diffusion effects, and 2) to provide quantitative estimates of cumulative release of radionuclides at the WIPP land-withdrawal boundary and at the stock well, at distances along the flow line of 3.6 and 6.0 km, respectively.

To simplify the Culebra transport calculations, it is assumed that the steady-state flow field in the Culebra is disturbed insignificantly by the fluid release from the breach borehole. To justify this approach, particle travel times in the Culebra dolomite, from the release point to the stock well location, were calculated for steady-state conditions and for Case IIA(rev) and Case IIC(rev) transient conditions. The particle travel time for the undisturbed, steady-state flow calculation differs by about 3 percent from the Case IIA(rev) particle travel time and about 5 percent from the Case IIC(rev) travel time. In addition, the location of the transport pathway for the three Culebra flow fields (steady-state, IIA[rev], and IIC[rev]) varied insignificantly.

Several other assumptions were used in implementing the two-dimensional approach for simulating transport in the Culebra. The theoretical contaminant plume width, Q/bu_o, was used to estimate the variation in plume width at the release point. Since the region of disturbed flow was relatively small compared to the transport distances to the WIPP site boundary and the stock well, the mass flux at any point in time was distributed in a uniform manner laterally from the point of release. The changing width of the input zone was handled by changing the number of input blocks on a line transverse to the flow. An average Darcy velocity was used in the transport simulations.

The rate of fluid release from the brine reservoir into the Culebra aquifer was calculated, taking into account degradation of the plugs installed in the intruding borehole when it was abandoned and depressurization of the brine reservoir. Then the analysis turns to the calculation of centerline radionuclide and stable lead concentrations in the downstream waste plume at the hypothetical stock well 3 mi away.

In calculating the transport of radionuclides and lead in the Culebra aquifer, the numerical model assumed that the amount of brine entering from the intruding borehole was small enough that the Culebra aquifer flow continued almost undisturbed.

The brine entering flows to the east, then south with the Culebra aquifer flow in a plume that slowly widens down-flow. Initially, the streamlines of brine flow spread out from the point of injection, but at a distance they become nearly parallel to the direction of natural groundwater flow (Figure 5.7).

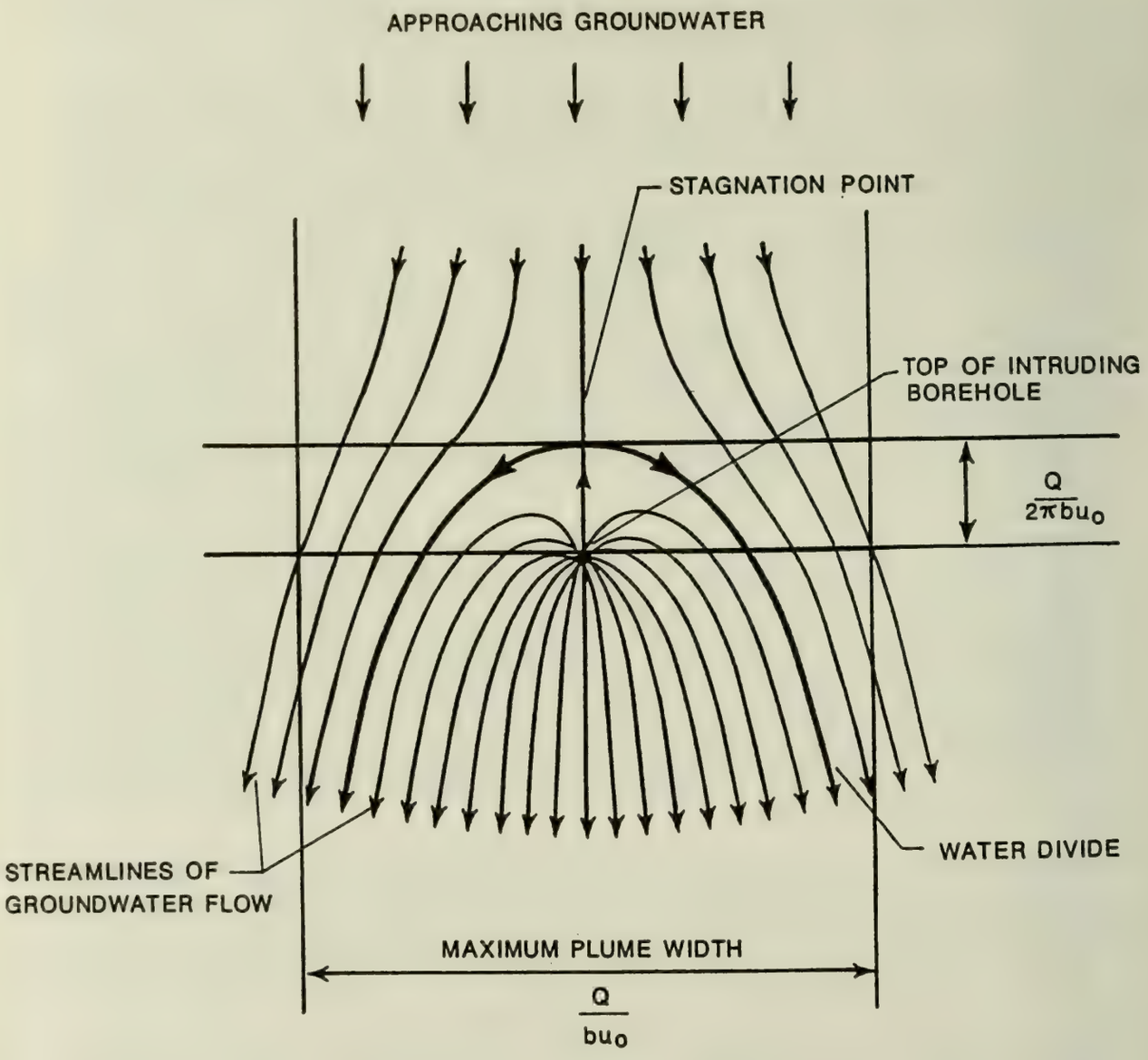
Asymptotically, the streamlines of the injected fluids form a plume of contaminated water of width Q/bu_o, where Q is the rate of fluid release, b is the aquifer thickness, and u_o is the natural groundwater flux. Also, the flux within the plume approaches that of the natural groundwater. The plume width and stagnation distance also provide a measure of the extent of disturbance to the natural flow. The maximum rate of fluid release (Q_{max}) and the natural groundwater velocity (u_o) at the point of injection yield the stagnation-point distances and the plume widths shown in Table 5.65.

The fluid flowing from the borehole into the Culebra consists of both brine flow from the Castile brine reservoir and brine inflow into the waste disposal rooms from the Salado Formation. In Cases IIA and IIA(rev), radionuclide concentrations and flow rates into the Culebra are nearly constant, because flow out of the brine reservoir is too slow to deplete the reservoir appreciably during the 10,000-year time span considered here, and because at a waste solubility of only 10^{-6} M, no radionuclide is depleted from the stored wastes. In all other Case II scenarios, the increased borehole plug permeability depletes the brine reservoir appreciably during the 10,000 years (Figure 5.8). In Cases IIB and IID, brine from the Castile reservoir does not interact directly with the waste, but inflow from the Castile continues. As a result, a nearly constant amount of Salado brine mixes with a decreasing amount of Castile brine and concentrations of radionuclides input to the Culebra tend to increase with time. (The greater radionuclide solubility in Case IIB than in IID means some depletion of some radionuclides in the waste, complicating the picture.) In Cases IIC and IIC(rev), the Castile brine flowing up the borehole is free to mix with the waste, severely depleting some of the radionuclides in it. The radionuclide concentrations input into the Culebra therefore decrease with time.

Another effect of a time-varying rate is that the plume width changes. Table 5.65 indicates that the stagnation-point distance decreases by a factor of 15 over the 10,000-year time scale being considered for Cases IIB and IIC and by a factor of 18 for Case IID. However, because these changes are slow, the plumes can be treated as quasi-steady-state phenomena.

Input Parameters to the Model. Some of the parameters assumed for these calculations are given in Tables 5.66 and 5.67.

For the most part, these parameters are the same for all six cases. The same brine reservoir assumptions are made throughout (Table 5.66). In Table 5.67, the permeability of the borehole was assumed to be 10 times larger for Cases IIB, IIC, and IIC(rev) and IID than for Cases IIA and IIA(rev); this accounts for the 10 times greater initial rates of fluid injection shown in Table 5.65. Similarly, the solubility of waste radionuclides in brine was assumed to be 100 times greater in Cases IIB, IIC, and IIC(rev) than in Cases IIA, IIA(rev), and IID. Brine inflow from the Salado was 10 times larger in Cases IIA, IIA(rev), IIB, IIC, and IIC(rev) than in IID. Culebra flow projections were degraded to make the groundwater flow faster and easier in Cases IIB, IIC, IIC(rev), and IID than in IIA, and IIA(rev).



NOTE: Q = RATE OF FLUID RELEASE, m^3/s

b = AQUIFER THICKNESS, m

u_o = GROUNDWATER FLOW , m/s

REF: LAPPIN et al., 1989.

FIGURE 5.7

DIAGRAM OF GROUNDWATER FLOW NEAR THE POINT WHERE WATER FROM THE INTRUDING BOREHOLE ENTERS CULEBRA AQUIFER FLOW

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TABLE 5.65 Characterization of the waste plume within the Culebra from point of release to stock well

	Case IIA	Case IIA(rev)	Cases IIB, IIC	Case IIC(rev)	Case IID
Distance from release to stagnation point					
- at end of borehole plug operation	7.8 m	2.9 m	69.6 m	24.6 m	68.8 m
- at 10,000 yr	5.6 m	2.3 m	4.7 m	2.7 m	3.8 m
Theoretical plume width at end of borehole plug degradation					
- near release point	49.2 m	18.2 m	437 m	154 m	432 m
- at WIPP-site boundary	-----	19.7 m	-----	167 m	-----
- at stock well	21.1 m	17.4 m	188 m	148 m	186 m
Theoretical plume width at 10,000 yr					
- near release point	35.2 m	14.3 m	29.3 m	17.1 m	24.0 m
- at WIPP-site boundary	-----	15.5 m	-----	18.5 m	-----
- at stock well	15.1 m	13.7 m	12.5 m	16.3 m	10.3 m
Brine reservoir discharge rage [Q_b]					
- at end of borehole plug degradation	9.89 m^3/yr	7.31 m^3/yr	98.1 m^3/yr	72.6 m^3/yr	98.1 m^3/yr
- at 10,000 yr	6.69 m^3/yr	5.44 m^3/yr	1.3 m^3/yr	6.78 m^3/yr	5.35 m^3/yr
Salado brine inflow rate [Q_s]	1.3 m^3/yr	1.4 m^3/yr	1.3 m^3/yr	1.4 m^3/yr	0.1 m^3/yr
Total brine injection rate to Culebra [Q_b+Q_s]					
- at end of borehole plug degradation	11.2 m^3/yr	8.71 m^3/yr	99.4 m^3/yr	74.0 m^3/yr	98.1 m^3/yr
- at 10,000 yr	7.99 m^3/yr	6.84 m^3/yr	2.6 m^3/yr	8.18 m^3/yr	5.45 m^3/yr

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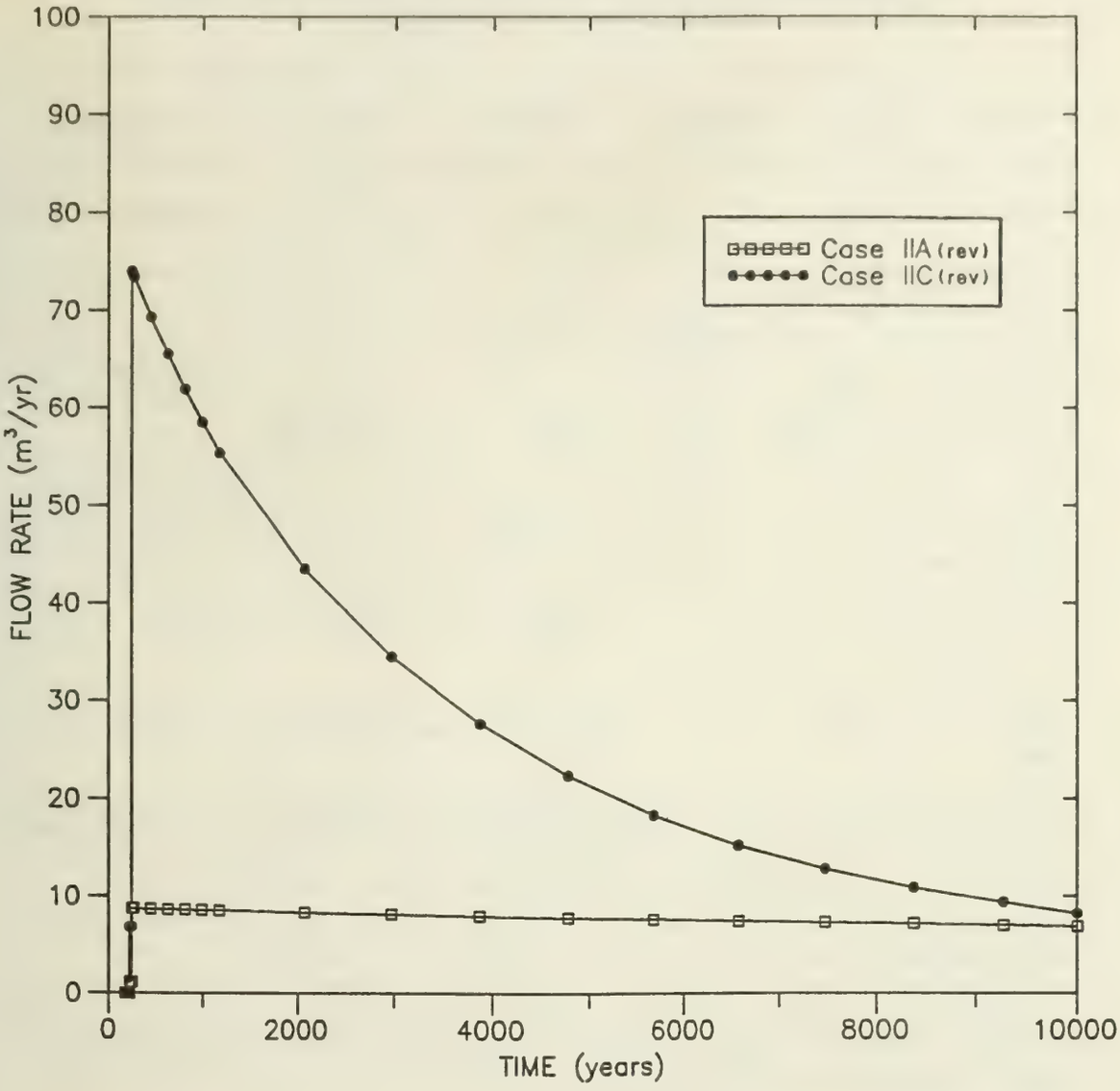
TABLE 5.65 Concluded

	Case IIA	Case IIA(rev)	Cases IIB, IIC	Case IIC(rev)	Case IID
Darcy velocity in Culebra					
- at release point	9.36×10^{-10} m/s	1.97×10^{-9} m/s	9.36×10^{-10} m/s	1.97×10^{-9} m/s	9.36×10^{-10} m/s
- at WIPP-site boundary	----	1.82×10^{-9} m/s	----	1.82×10^{-9} m/s	----
- at stock well	2.18×10^{-9} m/s	2.06×10^{-9} m/s	2.18×10^{-10} m/s	2.06×10^{-9} m/s	2.18×10^{-10} m/s
Average Darcy velocity in Culebra along transport pathway to the stock well	----	1.87×10^{-9} m/s	----	1.87×10^{-9} m/s	----

Source: Lappin et al., 1989, Table E-3; Lappin et al., 1990, to be published.



REF: LAPPIN et al., 1990.

FIGURE 5.8
FLOW RATES TO THE CULEBRA DOLOMITE FROM THE BREACH BOREHOLE FOR CASES IIA (REV) AND IIC (REV)

TABLE 5.66 Base-case and range of values of parameters describing the brine reservoir

Parameter	Symbol	Base-case	Range	Units
Initial pressure	P_i	12.7	7.0 to 17.4	MPa
Effective thickness	b	7.0	7.0 to 24.0	m
Transmissivity of inner zone	T_i	7×10^{-4}	7×10^{-6} to 7×10^{-2}	m^2/s
Distance to intermediate zone contact	r_2	300	100 to 900	m
Transmissivity of intermediate zone	T_o	7×10^{-6}	7×10^{-8} to 7×10^{-4}	m^2/s
Distance to outer zone contact	r_3	2000	30 to 8600	m
Transmissivity of outer zone	T_m	1×10^{-11}	Constant	m^2/s
Fluid density	ρ_f	1240	Constant	kg/m^3
Porosity	ϕ	0.005	0.001-0.01	
Compressibility of medium	α	1×10^{-9}	1×10^{-10} to 1×10^{-8}	1/Pa

Source: Lappin et al., 1989, Table E-4.

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TABLE 5.67 Specifications for intrusion borehole for Case II simulations

Parameter	Value	Units
Borehole diameter	0.334	m
Effective borehole permeability		
- Open borehole between plugs	infinite	
- plug in Castile	10^{-15}	m^2
- plugs in Salado	10^{-18}	m^2
- for times greater than 150 yr		
- Case IIA, IIA(rev)	10^{-12}	m^2
- Case IIB, IIC, IIC(rev), IID	10^{-11}	m^2

Source: Lappin et al., 1989, Table E-2.

These differences are summarized in Table 5.57.

Radionuclide Concentrations at the Stock Well. Figure 5.8 contrasts the brine inflow rates into the Culebra for Cases IIA(rev) and IIC(rev). (Those for IIB, IIC, and IID will be like those for IIC[rev]). Here, time starts when the plugs in the borehole begin to fail at 75 years after emplacement; then, for ease in computation, they are assumed to fail in steps at 75, 100, 125, and finally at 150 years. The initial flow in Case IIC(rev) at 75 years is 10 times greater than that in Case IIA(rev); then the rate decreases sharply as the Castile Formation brine reservoir depletes. The lower initial flow in Case IIA(rev) (due to a lower borehole permeability, as shown in Table 5.67) depletes the reservoir much more slowly, and the curve is nearly flat for the 10,000 years calculated. At 10,000 years, the flow in Case IIA(rev) and IIC(rev) are about the same.

For all radionuclides considered, Cases IIA and IIA(rev) estimate concentrations of less than 10^{-16} kg/kg at the stock well for over 10,000 years (Table 5.68). Figures 5.9 and 5.10 show how the concentrations vary with distance from the intruding borehole at 10,000 years for stable lead and three radionuclides in the Pu-238 chain for Case IIA(rev).

Contaminant Transport for Case IIA(rev). Figure 5.9 shows how the Case IIA(rev) concentration of stable lead varies with distance from the intruding borehole at 10,000 years. The centerline concentration is reduced from the solubility-limited concentration of the injected brine, 5.4×10^{-5} kg/kg, by about a factor of ten; in the draft SEIS the early concentrations were about equal to the solubility limit. This reduction is due to lateral dispersion effects, which are more accurately simulated in the revised two-dimensional transport model used for Cases IIA(rev) and IIC(rev) than in the earlier model.

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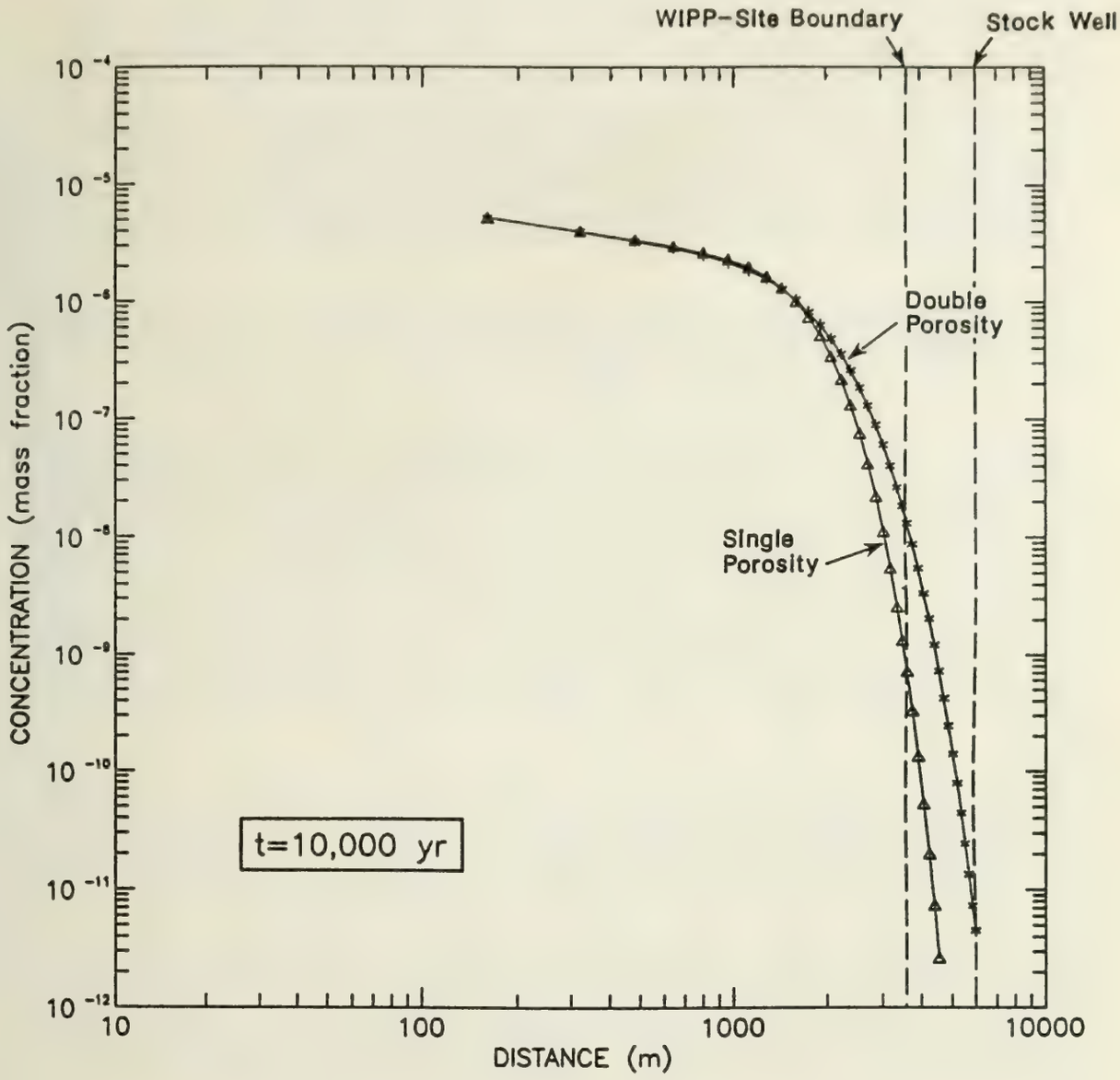
TABLE 5.68 Radionuclide concentrations in the Culebra aquifer at the stock well at 10,000 years[a]

Nuclide	Case IIA[b] (kg/kg brine)	Case IIA(rev)[b] (kg/kg brine)	Case IIB (kg/kg brine)	Case IIC (kg/kg brine)	Case IIC(rev) (kg/kg brine)	Case IID (kg/kg brine)
Np-237	nr[c]	4.91×10^{-20}	8.37×10^{-9}	2.98×10^{-8}	2.01×10^{-9}	2.57×10^{-10}
Pb-210	7.61×10^{-19}	3.12×10^{-21}	1.20×10^{-13}	4.15×10^{-14}	7.80×10^{-14}	1.46×10^{-15}
Pu-239	nr	0	8.36×10^{-10}	4.14×10^{-14}	6.54×10^{-10}	6.58×10^{-13}
Pu-240	nr	0	1.07×10^{-10}	2.32×10^{-14}	2.34×10^{-11}	3.83×10^{-13}
Ra-226	5.46×10^{-17}	2.40×10^{-19}	8.63×10^{-12}	2.98×10^{-12}	6.12×10^{-12}	1.05×10^{-13}
Th-229	nr	2.31×10^{-26}	3.65×10^{-11}	1.58×10^{-11}	1.33×10^{-11}	1.52×10^{-13}
Th-230	8.21×10^{-23}	1.43×10^{-26}	9.01×10^{-12}	3.57×10^{-12}	4.37×10^{-12}	1.20×10^{-13}
U-233	nr	3.00×10^{-22}	2.92×10^{-8}	8.59×10^{-8}	6.29×10^{-9}	2.55×10^{-10}
U-234	1.68×10^{-18}	2.67×10^{-22}	7.94×10^{-9}	2.86×10^{-8}	2.05×10^{-9}	2.56×10^{-10}
U-236	nr	3.02×10^{-22}	7.71×10^{-9}	8.84×10^{-9}	3.47×10^{-9}	7.40×10^{-11}

[a] 1,500 years for Case IIC.
[b] Concentrations below 10^{-16} are not considered significant.
[c] nr = not reported.



REF: LAPPIN et al., 1990.

FIGURE 5.9
CONCENTRATION PROFILES ALONG THE PLUME CENTERLINE FOR STABLE PB AT 10,000 YEARS, CASE IIA (REV)

Figure 5.9 also shows the effect of the dual-porosity-transport capability now incorporated into the SWIFT II code. Profiles for stable Pb were calculated using both the single porosity and the double porosity assumptions in Case IIA(rev), with the porosity for the single porosity profile set equal to the sum of the fracture and matrix porosities. The two profiles are in relatively good agreement in the first segment of the travel path, but at larger distances, contaminant transport is more strongly influenced by the fractures, resulting in earlier arrivals and higher concentrations at any given time. At the WIPP-site boundary, the double porosity calculation yields about 10^{-8} kg/kg at 10,000 years, whereas the single porosity prediction is lower by a factor of about 20.

Figure 5.13 shows the effect of lateral dispersion for Case IIC(rev). The concentration of stable lead decreases from its centerline value at the stock well to about 4 percent of that value at a lateral distance of 950 m.

Figure 5.10 shows how concentrations at 10,000 years vary with distance from the injection point for four radionuclides in the Pu-238 chain. Here too the centerline concentrations are reduced by lateral dispersion. Typical of many of the radionuclides near the injection point in these revised calculations, the profile of U-234 is reduced by a factor of about 15 relative to the solubility-limited concentration (2.4×10^{-7} kg/kg) of the injected fluid. Ra-226 and U-234 have built up to concentrations at the site boundary of somewhat over 10^{-16} kg/kg, but neither these two radionuclides nor the radionuclides in other decay chains (not shown here) have reached that level at the stock well by 10,000 years. For that reason, the human exposure at 10,000 years inferred from Case IIA(rev) is very low, yielding a total just under 10^{-6} mrem/yr (Table 5.68).

Contaminant Transport for Case IIC(rev). Case IIC(rev) uses a highly degraded set of parameters to characterize the repository-geosphere system under intrusion conditions. Like Case IIA(rev), the Case IIC(rev) analysis has been updated to include lateral dispersion effects, species-specific diffusion, and the revised Culebra flow field.

Figure 5.11 shows how the Case IIC(rev) concentration of stable lead varies with distance from the intruding borehole for both single and double porosity flow. Again the centerline concentrations are reduced by lateral dispersion from the solubility-limited concentration at the point of injection, 5.4×10^{-5} kg/kg. Figure 5.12 shows lead concentrations as a function of time at the stock well for single and double porosity flow.

These profiles and these time histories indicate a significant difference between the single-and double-porosity calculations. In the double-porosity calculation, the main pulse has already gone past the stock well, while in the single-porosity case it has not arrived, having travelled only 2,500 m from the injection point. This illustrates the strong effect of fractures on contaminant transport.

Figure 5.14 shows how concentrations vary with distance from the injection point for four radionuclides in the Pu-238 chain. Again, centerline concentrations are reduced. Figure 5.15 shows how the concentrations at the stock well for the Pu-238 chain change with time.

Calculations for the other radionuclide chains show similar effects.

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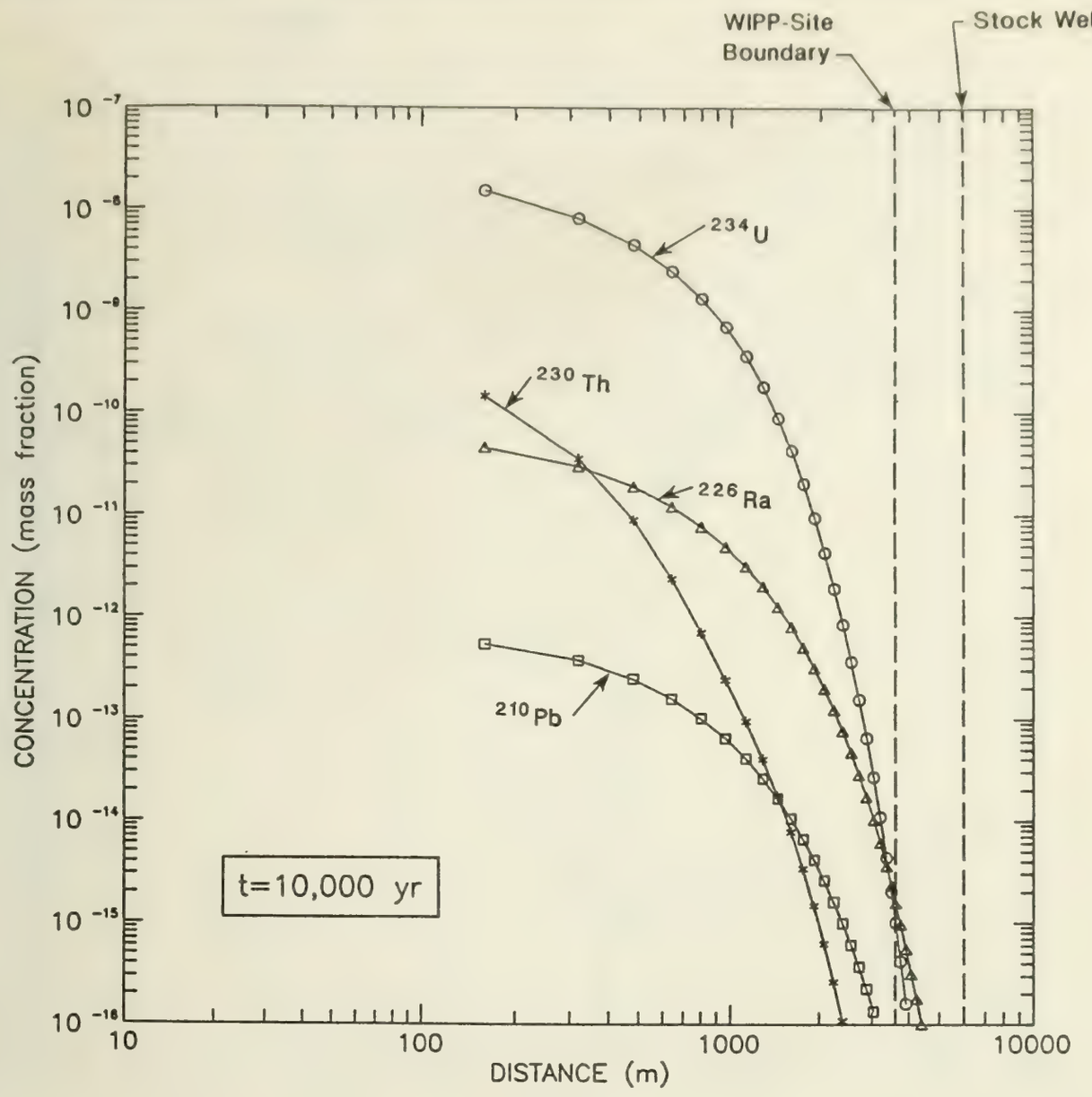
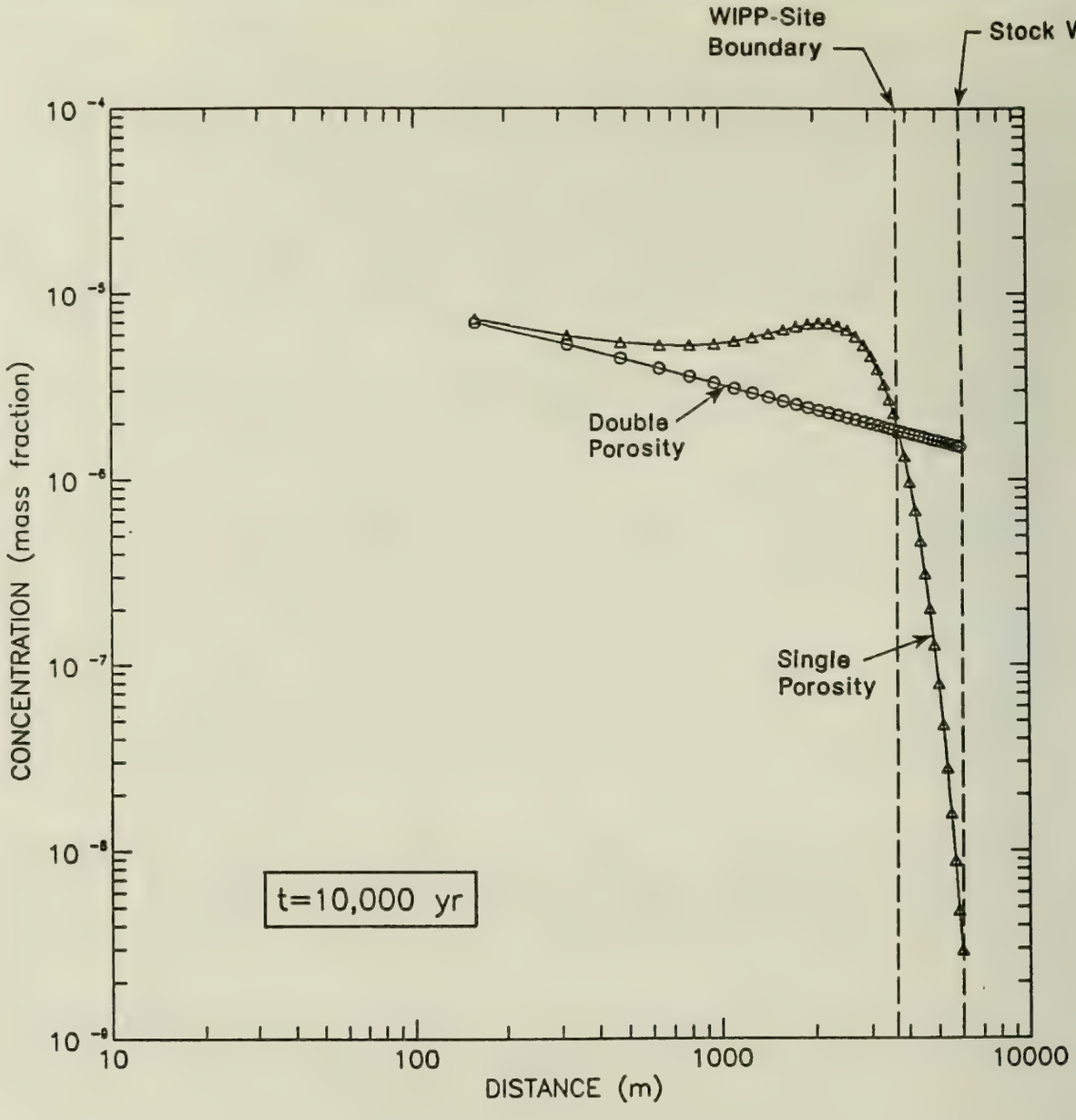


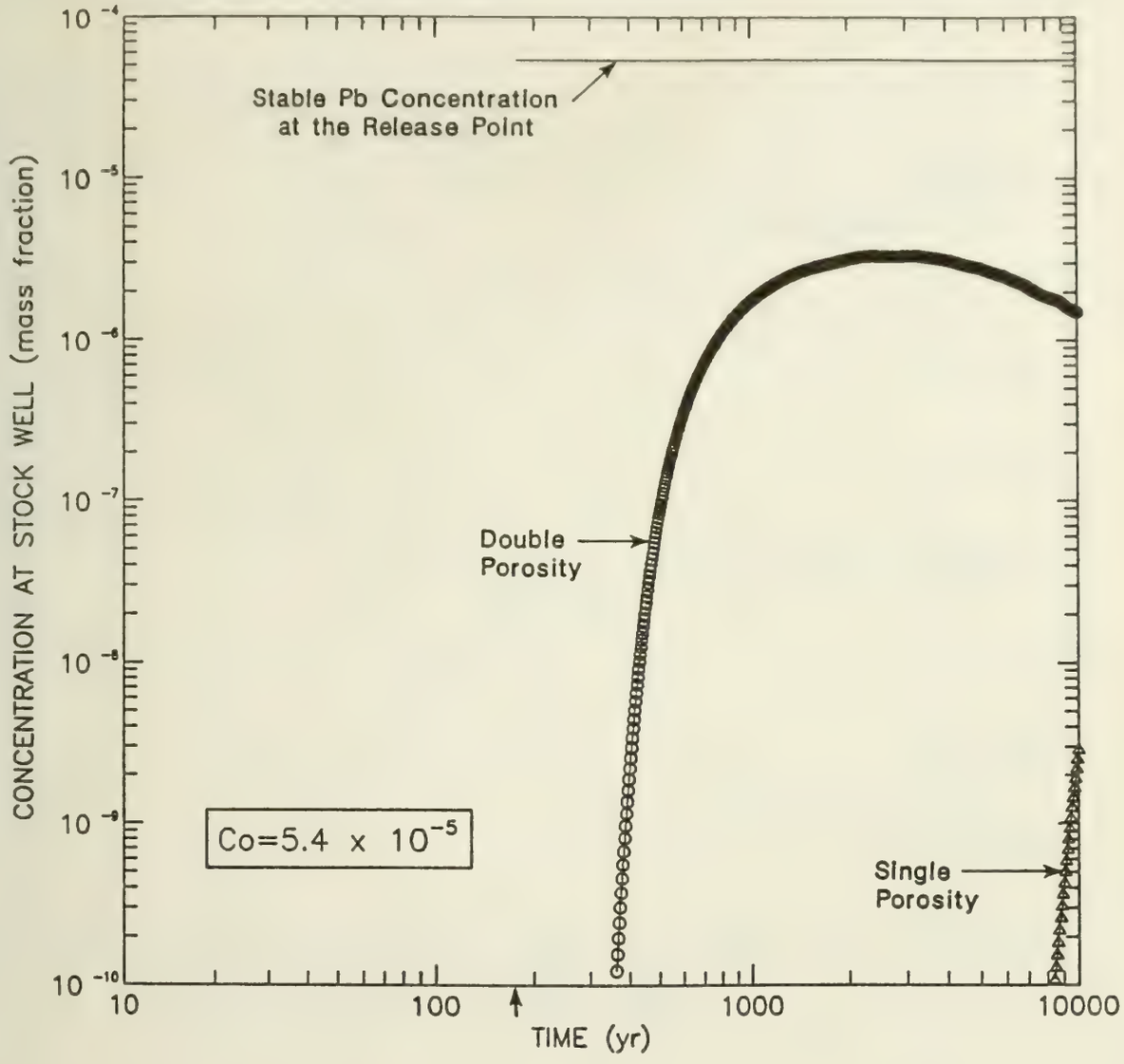
REF: LAPPIN et al., 1990.

FIGURE 5.10
CONCENTRATION PROFILES ALONG THE PLUME CENTERLINE FOR ^{238}PU DECAY CHAIN AT 10,000 YEARS, CASE IIA (REV)



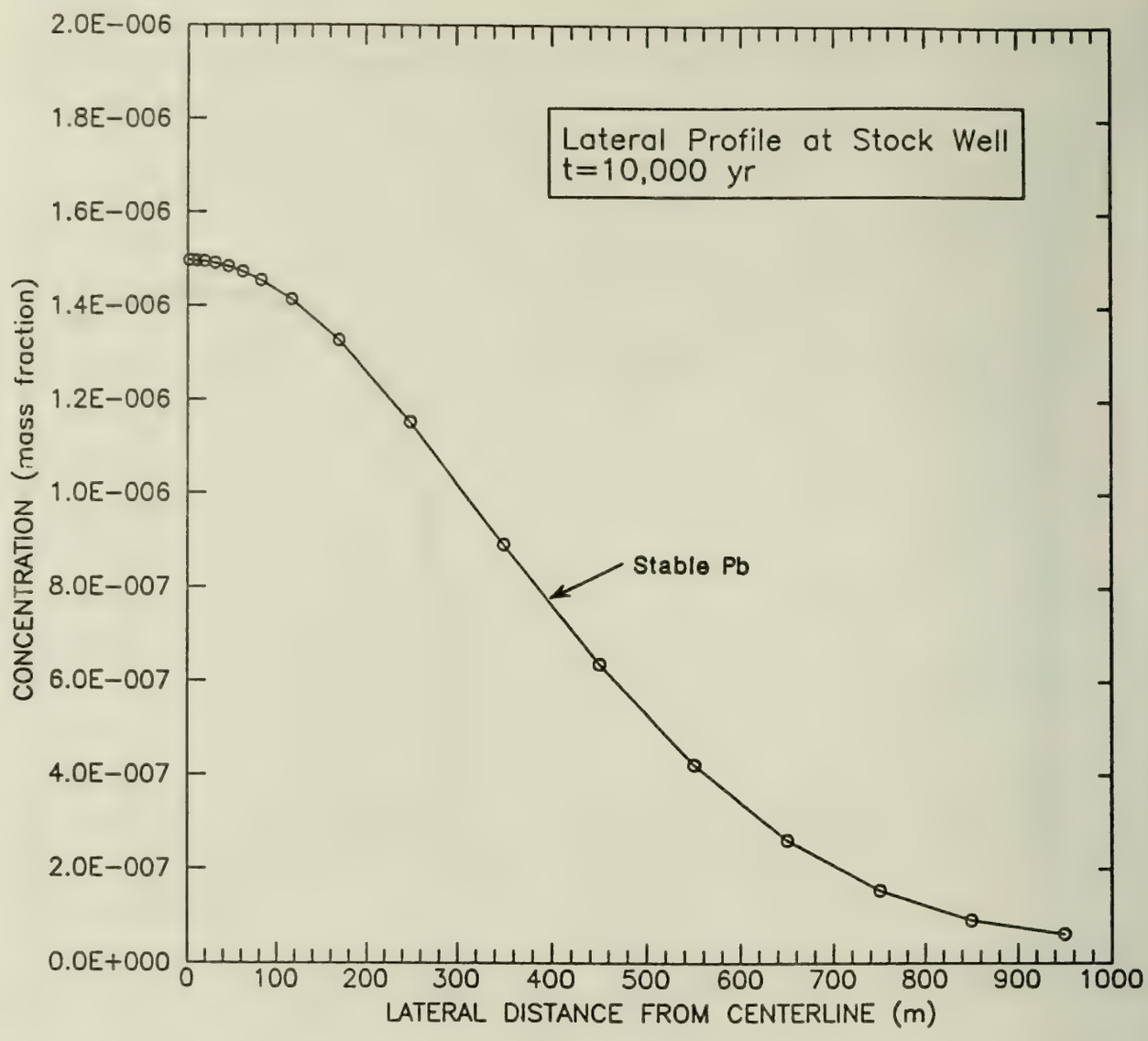
REF: LAPPIN et al., 1990.

FIGURE 5.11
CONCENTRATION PROFILES ALONG THE PLUME CENTERLINE FOR STABLE PB AT 10,000 YEARS, CASE IIC (REV)



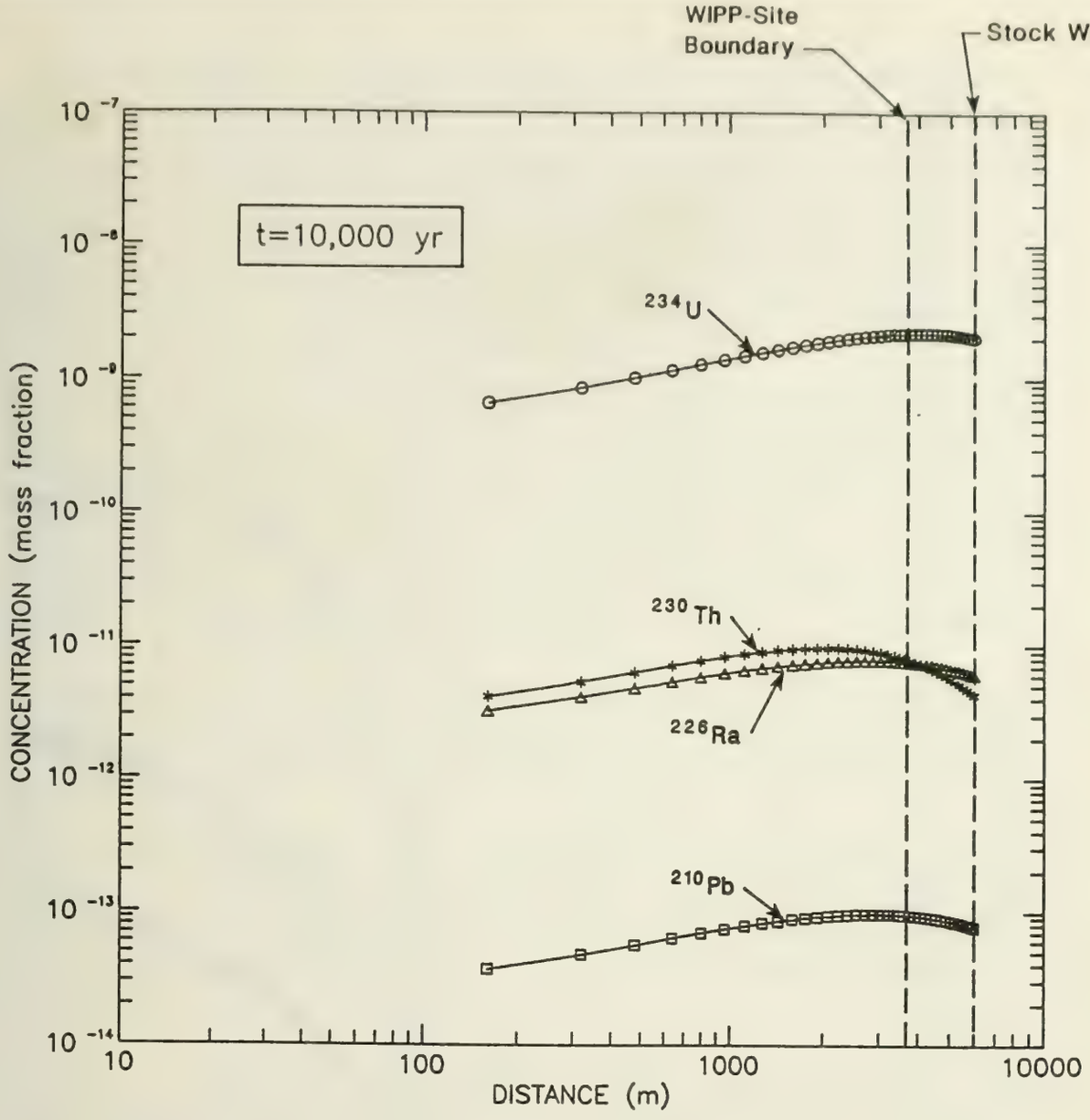
REF: LAPPIN et al., 1990.

FIGURE 5.12
BREAKTHROUGH CONCENTRATIONS AT STOCK WELL FOR STABLE PB AS A FUNCTION OF TIME, CASE IIC (REV)



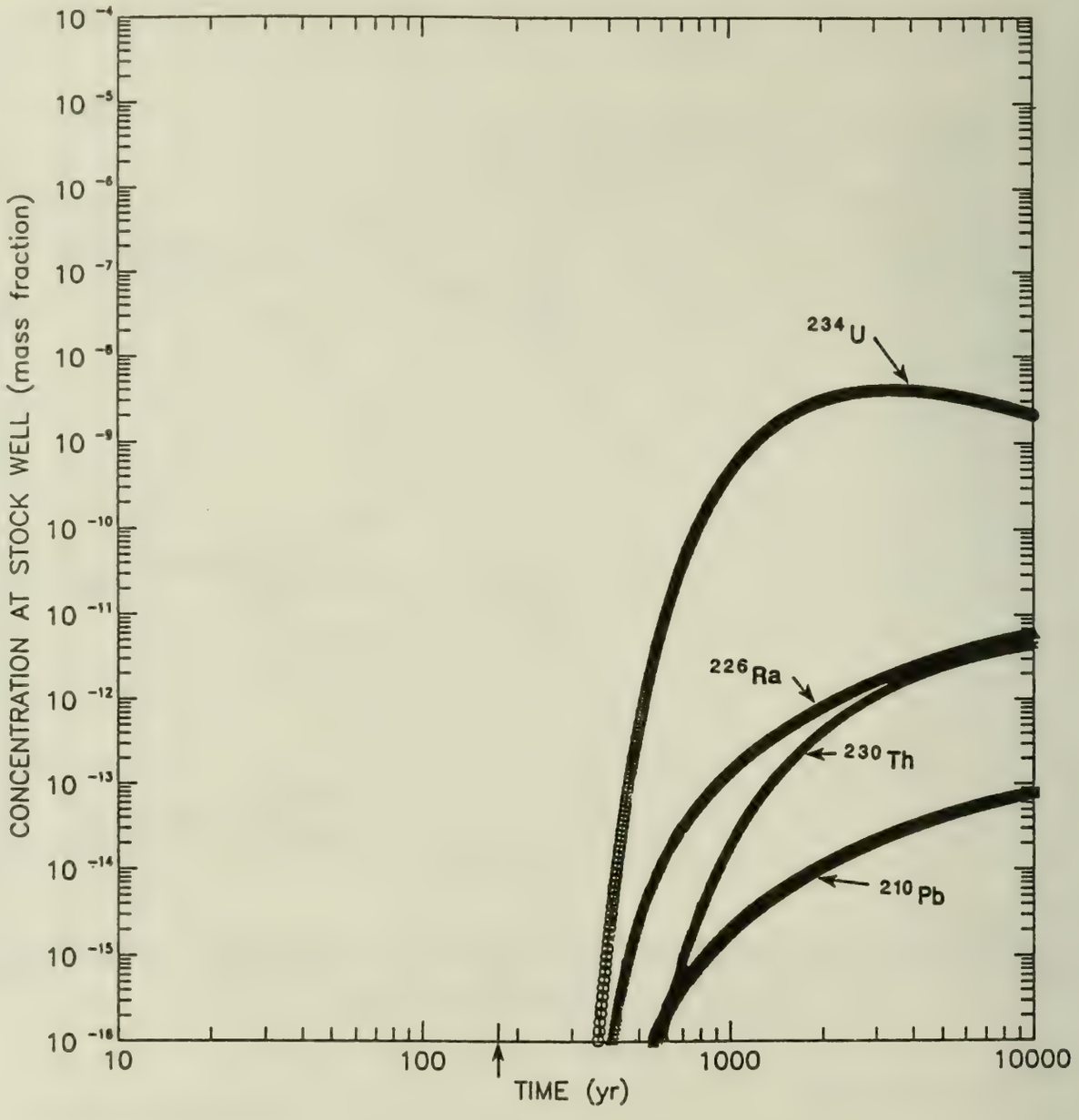
REF: LAPPIN et al., 1990.

FIGURE 5.13
LATERAL CONCENTRATION PROFILE AT STOCK WELL FOR STABLE PB AT 10,000 YEARS, CASE IIC (REV)



REF: LAPPIN et al., 1990.

FIGURE 5.14
CONCENTRATION PROFILES ALONG THE PLUME CENTERLINE FOR 238PU DECAY CHAIN AT 10,000 YEARS, CASE IIC (REV)



REF: LAPPIN et al., 1990.

FIGURE 5.15
BREAKTHROUGH CONCENTRATIONS AT STOCK WELL FOR ^{238}PU DECAY CHAIN AS A FUNCTION OF TIME, CASE IIC (REV)

Table 5.69 quantifies the changes in Culebra transport parameters that cause the qualitative difference between Cases IIA and IIA(rev) and the other cases. For Cases IIB, IIC, IIC(rev), and IID, porosity is reduced from 16 to 7 percent. The distribution coefficients K_d are also reduced, so that there is less retardation: for Pb and Ra this reduction is from 0.1 to 0.05 ml/g. The fracture spacing is increased from 2 to 7 m, so that, the fracture porosity remaining the same, the fracture widths increase from 0.3 to 1.0 cm. These and other changes all increase the rate of fluid transport in the fractures above that of Cases IIA and IIA(rev). Increasing the fracture spacing also decreases the area of matrix exposed to the fluid by a factor of 3.5, thereby reducing the opportunity for diffusion into the matrix to occur.

Radiation Exposures from Stock Well Water. All six variants of Case II assume that water pumped from the stock well is given to cattle grazing in the area. The human exposures calculated here would be to a person who eats beef from those cattle. The calculations assume that 8 cattle graze in the square mile (2.6 km^2) around the well. Each animal would require 13 gal/day (50 L/day) of water to drink. Thus, allowing for rainfall at the rate of 20 cm/yr and evaporation at the rate of 200 cm/yr and a stock pond whose area is 139 ft^2 (0.0013 hectare), means that this well must be pumped at the rate of 120 gal/day (460 L/day). All this results in an evaporation-caused increase in radionuclide concentrations of a factor of 1.1635.

Next, assuming that the maximally exposed individual eats beef from these cattle at the rate of 86 g/day (NCRP, 1984) and using the usual transfer coefficients for relating the amount of food eaten to exposure of various body organs, the calculation yields the individual committed doses per year of exposure shown in Table 5.70.

These numbers are based on the cattle having been drinking from the stock well long enough to come to equilibrium with the radionuclides in its water. (That is, the calculations use meat transfer coefficients that assume that steady-state conditions have been reached [Baes et al., 1984].) As the cattle continue to use this water, the radionuclide concentrations in their muscle tissue build up according to the factor

$$1 - \exp(-\lambda t),$$

where λ is equal to $\ln(2)/T_{1/2}$, $T_{1/2}$ being the effective or biological half-life of the radionuclide in muscle tissue, and t is the length of time the animal uses the contaminated water.

The value used by the Nevada Applied Ecology Group for the biological half-life of Pu-239 in muscle is 2,000 days (Martin and Bloom, 1980). The Environmental Evaluation Group suggests a value of 200 days for t (Neill, 1989, p. 57). The non-equilibrium correction factor then becomes 0.067.

Assuming that this factor also applies to other radionuclides, the human exposures given in Table 5.70 can be reduced by a factor of 15. Disregarding this factor, the committed doses shown are the maximum doses that the beef eater would receive during the first 10,000 years after the intruding borehole is abandoned and plugged. The earliest time this intrusion could occur is 100 years after the facility is decommissioned (40 CFR 191), because active institutional controls are assumed to

TABLE 5.69 Parameter base-case and range values selected for the Culebra dolomite

Parameter	Symbol	Base Case	Range	Units
Free-water diffusivity	D'	5×10^{-6}	5×10^{-7} - 9×10^{-5}	cm^2/s
- Radionuclides - Case IIA,	D'	1×10^{-6}	NA	cm^2/s
- Cases IIB, IIC, IID	D'	5×10^{-7}	NA	cm^2/s
- Stable Pb - Case IIA,	D'	4×10^{-6}	NA	cm^2/s
- Cases IIB, IIC, IID	D'	2×10^{-6}	NA	cm^2/s
Cases IIA(rev), IIC(rev)		See Table I.2.1.3		
Matrix tortuosity		0.15	0.03 - 0.5	
- Cases IIA, IIA(rev)		0.15	NA	
- Cases IIB, IIC, IIC(rev), IID		0.03	NA	
Fracture spacing	2L'	2.0	0.25 - 7.0	m
- Cases IIA, IIA(rev)	2L'	2.0	NA	m
- Cases IIB, IIC, IIC(rev), IID	2L'	7.0	NA	m
Porosity	ϕ	0.16	0.07 - 0.30	
- Cases IIA, IIA(rev)	ϕ	0.16	NA	
- Cases IIB, IIC, IIC(rev), IID	ϕ	0.07	NA	
Fracture porosity	ϕ	1.5×10^{-3}	1.5×10^{-4} - 1.5×10^{-2}	
Matrix distribution coefficient				
- Cases IIA, IIA(rev):				
Plutonium	K_d	50	-	ml/g
Americium	K_d	200	-	ml/g
Uranium	K_d	1	-	ml/g
Neptunium	K_d	1	-	ml/g
Thorium	K_d	50	-	ml/g
Radium	K_d	0.1	-	ml/g
Lead	K_d	0.1	-	ml/g
- Cases IIB, IIC, IIC(rev), IID:				
Plutonium	K_d	25	-	ml/g
Americium	K_d	100	-	ml/g
Uranium	K_d	1	-	ml/g
Neptunium	K_d	1	-	ml/g
Thorium	K_d	25	-	ml/g
Radium	K_d	0.05	-	ml/g
Lead	K_d	0.05	-	ml/g

NA = Not Applicable.

Source: Lappin et al., 1989, Table E-6.

Note: The Culebra groundwater flow model presented in LaVenue et al. (1988) and in its revision referred to earlier was used for calculating fluxes and determining flow paths. The transient fracture flux along the flow path from the release point in the Culebra aquifer to the off-site stock well is calculated through hydraulic coupling of the brine reservoir, borehole region, and Culebra aquifer.

Table 5.70 Maximum 50-year committed doses incurred by an individual eating beef for 1 year that was watered at a stock well tapping a contaminated Culebra aquifer, for six scenarios (mrem during the 50 years following intake)

Nuclide	Case IIA	Case IIA(rev)	Case IIB	Case IIC	Case IIC(rev)	Case IID
Np-237	nr	1.35×10^{-11}	2.54	9.06	5.55×10^{-1}	7.81×10^{-2}
Pb-210	1.78×10^{-4}	6.65×10^{-7}	2.82×10^{1}	9.72	1.66×10^{1}	3.43×10^{-1}
Pu-239	nr	0	2.25×10^{-1}	1.11×10^{-5}	1.60×10^{-1}	1.77×10^{-4}
Pu-240	nr	0	1.06×10^{-1}	2.28×10^{-5}	2.09×10^{-2}	3.77×10^{-4}
Ra-226	3.02×10^{-5}	1.21×10^{-7}	4.77	1.64	3.07	5.79×10^{-2}
Th-229	nr	1.89×10^{-16}	3.28×10^{1}	1.42×10^{-1}	1.09×10^{-1}	1.36×10^{-3}
Th-230	1.06×10^{-14}	1.68×10^{-18}	1.16×10^{-1}	4.60×10^{-4}	5.12×10^{-4}	1.55×10^{-5}
U-233	nr	2.86×10^{-13}	3.06×10^{1}	9.02×10^{1}	6.00	2.67×10^{-1}
U-234	1.10×10^{-9}	1.58×10^{-13}	5.18	1.87×10^{1}	1.22	1.67×10^{-1}
U-236	nr	1.78×10^{-15}	5.01×10^{-2}	5.75×10^{-2}	2.05×10^{-2}	4.81×10^{-4}
Total	2.09×10^{-4}	7.85×10^{-7}	7.20×10^{1}	1.29×10^{2}	2.78×10^{1}	9.15×10^{-1}

Note: nr = not reported.

prevent the intrusion at any earlier time. At any later time the amount of radioactivity in the repository will be lower because of decay, but these calculations assume that the intrusion takes place at 100 years. The calculations only allow for radionuclide decay thereafter during the water-borne transport to the stock well.

In all cases except Case IIC, the greatest calculated potential for human exposure occurs at 10,000-years, the end of the period for which calculations were made. In these cases, the curves of dose vs. time are still rising at that time, implying that if the calculation had been continued past 10,000 years, a later, higher peak would have appeared. A late peak should not be surprising; a key purpose of geologic disposal is to delay the appearance of contaminants in the accessible environment for a very long time. (Calculations were only carried out to 10,000 years because that is the period specified in the EPA standards [10 CFR 191]. It is not to be inferred that there is no interest past that point, only that a repository with a reasonable expectation of performing well for that time will continue to be effective thereafter.)

In the calculations for the original Case IIC, discussed in the draft SEIS, a peak in the calculated dose appeared about 1,500 years after borehole abandonment. Another later peak was implied by the fact that the dose versus time curve was rising again at 10,000 years. The early peak came from two early contributors to that dose, U-233 and U-234, which peaked at that time. The dose versus time curve for the recalculated and more realistic Case IIC(rev) (Figure 5.16) shows no such early peak.

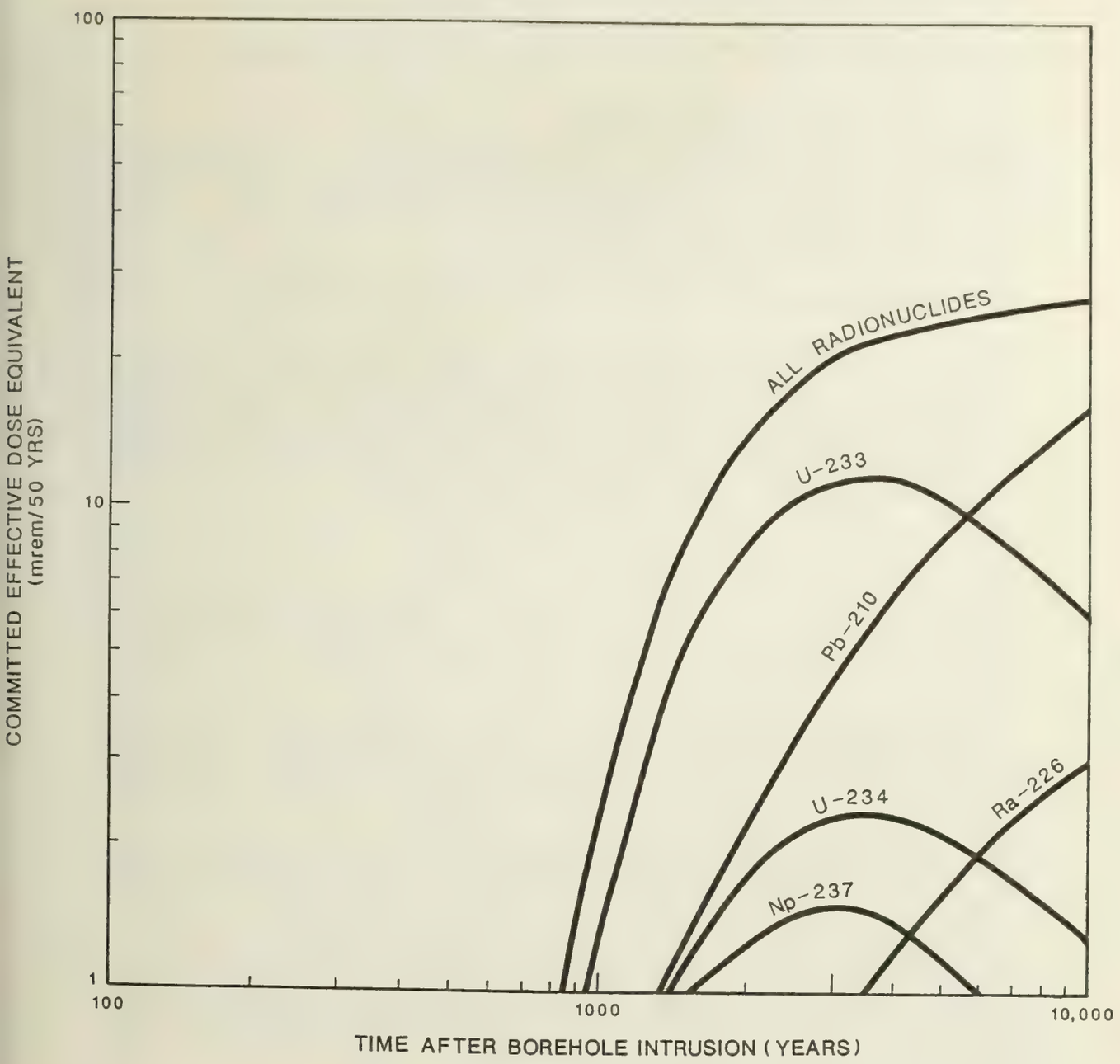
Figure 5.16 also shows the dose contributions of the five principal radionuclides entering into the total dose. Again U-233 and U-234 appear; but the Pb-210 peak (a short-lived but ever-replenished radionuclide) appears early enough and strong enough to fill in the dip observed in the original Case IIC between the early and late peaks.

With Case IIC(rev) replacing Case IIC (because it is technically more defensible in that the width of the contaminant plume was calculated instead of being estimated), and discounting IIB because it was not recalculated, the 28-mrem dose at 10,000 years shown in Table 5.70 for Case IIC(rev) is the highest committed dose that a person eating contaminated beef watered at the stock well would receive during the next 50 years as the result of a 1-year exposure. (A recalculated Case IIB would almost surely have given lower dose-time curves because of the lower amount of Salado brine inflow.) Thus this person would receive an average annual exposure of 0.6 mrem from that 1 year's commitment. If this person would continue to eat beef at this rate, in the 50th year, he or she would receive a 28-mrem radiation dose, about one-third of the 100-mrem average annual background radiation dose in the United States.

Lead Exposures from Stock Well Water. This calculation assumed that in Case IIC(rev), the more severe scenario, beef cattle drink water from the stock pond that contains the maximum concentration of lead (1.50 mg/L at 10,000 years) at the rate of 49 L (13 gal) per day. An average steer weighs 400 kg (Merck, 1979). A factor of 0.15 is used to account for the fact that not all of the lead ingested by cattle is retained in the beef (a portion of it will be excreted) (ATSDR, 1988). Thus, the cattle will ingest and retain lead at the rate of

$$1.50(\text{mg/L}) \times 49(\text{L/day}) \times 0.15/400(\text{kg}) = 0.028 \text{ mg/kg-day}.$$

The steer will not be harmed; it has been estimated that a mature steer will tolerate 6 mg/kg-day lead for 2 to 3 years (Botts, 1977).



NOTE: CONTRIBUTION OF FIVE PRINCIPAL RADIONUCLIDES AND ALL RADIONUCLIDES

FIGURE 5.16
RADIATION DOSES TO INDIVIDUALS WHO EAT BEEF FROM CATTLE WATERED AT THE STOCK WELL, CASE IIC (REV)

Then, assuming that the concentration of lead in the stock water remains constant throughout the lifetime of the steer, and that the ratio of the concentration of lead in the beef to that in the water is 3×10^{-4} $(kg/day)^{-1}$,

$$1.50(mg/L) \times 3 \times 10^{-4}(day/kg) \times 49(L/day) = 0.022\ mg(lead)/kg(beef)$$

will be available for human consumption.

As above, the daily beef consumption of an adult male (age 19 to 50) is assumed to be 0.086 kg (NCRP, 1984). An adult male body weight averages 70 kg. The daily human intake of lead, using the figure just calculated of 0.034 mg/kg of lead in the beef consumed and a gut partition factor of 0.15, is

$$0.022(mg/kg) \times 0.086(kg/day) \times 0.15/70(kg) = 4.1 \times 10^{-6}\ mg/kg\text{-}day.$$

The estimated daily intake of lead by humans calculated in this manner can be compared to the acceptable daily level for chronic intake (AIC) according to procedures described in the Superfund Public Health Evaluation Manual (EPA, 1986). A detailed explanation of the methodology used to estimate risk from exposure to noncarcinogens is provided in Appendix G. The AIC level for lead is 4.3×10^{-4} mg/kg-day (EPA, 1986). The calculated AIC-based hazard index for lead is therefore:

$$4.1 \times 10^{-6}/4.3 \times 10^{-4} = 0.0095.$$

This value is considerably less than one, indicating that the estimated intake of lead is well below the reference level. In other words, the ingestion of this concentration of lead every day throughout the life of the consumer will not result in adverse health effects.

For Case IIA(rev), the expected scenario, the maximum concentration of lead in the stock well is 4×10^{-6} mg/L. By ratioing the concentrations, the hazard index for Case IIA(rev) is 3×10^{-8}, considerably less than CASE IIC(rev).

5.4.2.7 Another Scenario Not Evaluated in Detail. The Environmental Evaluation Group has suggested a discussion of another scenario.

Two-Hole Breach Scenario. The basic two-hole scenario consists of a borehole that passes through a waste panel and into a brine reservoir, then is sealed. Following sealing, the repository is assumed to fill with Salado brine and repressurize. Before the first borehole plug deteriorates, a second borehole is drilled into the same waste panel, which now is full of brine under pressure and into the brine reservoir. The possible impacts of this second hole are:

- The initial pressure in the repository upon penetration of the second borehole should be close to that assumed in the Case IIA(rev) and IIC(rev) calculations. This would mean little change in the early-time release to the drill crew and down-wind ranch family, at most another geologist would receive a direct exposure to a cuttings sample and a doubling of exposure of the ranch family.

- When both penetrating boreholes have degraded, the initial release rates through the two holes to the Culebra could be as much as twice the rates calculated in the single borehole scenario. However, depletion of the brine reservoir would occur at a faster rate as well. The net amount of radioactivity released into the Culebra should be about the same as in Case II.

- For long-term releases, the two-hole scenario for base-case parameters (those of Case IIA[rev]) is bounded by the degraded parameter cases examined in the SEIS (such as Case IIC[rev]). The degraded single-borehole scenarios assume full circulation of Castile brine throughout the waste panel, which is very conservative for a single-borehole scenario; such circulation is much more likely for a two-hole scenario. The increased flow to the Culebra through two holes instead of one is bounded by the factor of 10 increase in borehole permeability assumed in the degraded parameter cases (especially Case IIC[rev]).

5.4.2.8 Summary and Observations. Nine calculations covering two basic scenarios have been made for this SEIS for the WIPP. Three of these treat the undisturbed repository (Cases IA, IB, and IC). (Case IA is essentially the same long-term scenario as the one treated in the No-Migration Variance Petition [DOE, 1989c].) Cases IA and IB remain essentially unchanged from the draft SEIS. They predict no radionuclides reaching the Culebra aquifers or the surface until well after 10,000 years (see Table 5.60); therefore, there is no human exposure for at least 10,000 years. In Case IC the tunnel and shaft seals are assumed to have nearly completely failed. In that case, radioactivity reaches the Culebra in 400 years, but it doesn't reach the stock well until 220,000 years have passed.

The six Case II calculations treat the long-term effects of waste material carried into the Culebra by brine from an underlying brine reservoir. Four of these six (Cases IIA, IIB, IIC, and IID) were reported in the draft SEIS; these four were calculated with a one-dimensional, stream-tube, single-injection-point version of the SWIFT II code. For this final SEIS, two of these calculations (Cases IIA[rev] and IIC[rev]) were repeated with a more realistic version of the SWIFT II code, one that incorporates two-dimensional transport with lateral diffusion, allows for a time-dependent width of the injection plume, and uses radionuclide-specific diffusivities. The code also had available an improved description of the transmissivity distribution field in the Culebra, based on more data than had been available for inclusion in the draft SEIS (see Subsection 4.3.3.3).

The two Case II calculations that were re-run describe the expected performance of the WIPP after intrusion, and its performance when the input parameters are degraded to near the extremes of their ranges. These results are generally to be preferred to the earlier versions, because they are based on a physically more realistic model.

Human Exposure. The predicted doses are listed in Table 5.70. These doses are "50-year committed effective dose equivalents," i.e., the total doses that a person would receive in the next 50 years from one year's exposure. In the cases treated in this SEIS, if the person exposed continues to eat this beef, his or her body burden of transuranic radionuclides continues to accumulate, and in the 50th year he or she receives a radiation dose numerically equal to the dose listed in Table 5.70.

(Under ICRP [1977, 1979], a committed dose is charged [in an accounting sense] against a person's radiation exposure during the year in which the commitment is incurred. For radionuclides with long residence times within the body, notably the transuranics of concern in this SEIS, this means that the dose is charged before it is actually received. This allows for the fact that in many instances, the radionuclide ingestion giving the committed dose is repeated year after year.)

Cases IA, IB, and IC treat the performance of the undisturbed repository. In Cases IA and IB, no radioactivity reaches the Culebra aquifers or the surface in 10,000 years, hence there is no possibility of human exposure in that time. (Case IA is essentially the same long-term release scenario as the one used in the No-Migration Variance Petition [DOE, 1989c].) In extreme circumstances (Case IC), radionuclides could reach the Culebra aquifer in 400 years but they do not reach the stock well until well after 100,000 years. Thus there is no human exposure within that time at the stock well.

In all versions of Case II, an intruding borehole brings radioactive material directly to the surface. If the hole is drilled soon after administrative control is given up (i.e., 100 years after facility closure), one of the crew members could receive a radiation dose of 91 mrem, effectively doubling his/her radiation exposure for that year. The dose received by members of a nearby ranch family would be at most a 0.77 mrem committed dose for each year of exposure.

Thereafter, brine flowing up from the brine reservoir continues to inject radioactive material into the Culebra aquifer. Downstream at the stock well, this activity reaches its maximum level at some time after the end of the 10,000-year time period for which calculations were made. The principal human exposure is again by way of the water-beef-man food chain.

Cases IIA and IIA(rev) treat the expected behavior of the disturbed repository. In Case IIA(rev), an individual eating beef from cattle that drink from the stock well at 10,000 years could receive a committed dose of about 10^{-6} mrem for each year of exposure. This dose is much smaller than variations of natural background levels from place to place around the country.

Cases IIB, IIC, IIC(rev), and IID treat the performance of the disturbed repository under various conditions of site degradation and mitigation (Table 5.57). Cases IIC and IIC(rev) treat the repository and surrounding geosphere with groundwater transport properties degraded to near the extremes of their expected ranges (Appendix I.2), but without any attempt at mitigation by waste compaction or backfill treatment. Cases IIB and IID treat the repository and surrounding geosphere with degraded transport properties, and also with mitigation to the extent that brine flowing up out of the brine reservoir is precluded from circulating within the waste disposal rooms.

Case IIC(rev) predicts a total committed dose of only 28 mrem, even without allowing for the beef cattle not reaching equilibrium with the stock well water. (Projected exposures are still rising at 10,000 years, implying a higher peak some time later.) Inasmuch as the predicted dose for the original IIC was greater than those for Cases IIB and IID, it is likely that recalculated predictions of the latter two cases would be lower than that of Case IIC(rev).

Table 5.65 indicates that for Cases IIB through IID the flow of brine up through the drill hole is so great that the brine reservoir is nearly exhausted by 10,000 years. The flow is also so great that the waste disposal panel "soon" (in a few thousand years) begins to be depleted of some of its radionuclides, and the dissolved radionuclides enter the Culebra groundwater as a pulse. Downstream, sorption in the rock matrix retards the radionuclides differently (i.e., they have different K_ds), and their peaks arrive at the stock well at different times (Figure 5.16). U-233, U-234, and Np-237 peak at about 3000 years, while Pb-210 and Ra-226 peak levels are greatest at the end of the 10,000-year period calculated.

(In the original Case IIC, a similar figure [Figure 5.15 of the draft SEIS] had a peak at about 1,500 years. This was caused by the peaks for the individual radionuclides having different relative strengths. In Case IIC[rev] the actual peak potential exposure is at the end of the 10,000-year period calculated, with the curve still rising.)

In summary, the undisturbed repository is not expected to release any radioactive materials past the site boundary in well over 100,000 years (Cases IA and IB), even if the tunnel and shaft seals have nearly completely failed (Case IC).

On the other hand, in all six Case II intrusion scenarios, radioactive material is brought to the surface immediately. If the hole is drilled soon after administrative control of the site is given up, one of the drill crew may double his/her radiation exposure from natural background for that year; if later, his/her exposure is well below natural variations in background. This exposure is also well within the usual guidelines: the ICRP recommends (ICRP, 1977) and the DOE has adopted a 100 mrem/yr general dose limit for a member of the general public from human practices other than in the medical field. A ranch family assumed to live near the well head will also only receive minimal exposure.

The expected long-term behavior of the disturbed repository is also small (Cases IIA and IIA[rev]). If, however, the groundwater parameters are considerably poorer than expected (Case IIC[rev]), the committed doses are more appreciable, 28 mrem per year of exposure, though still within the ICRP and DOE guidelines.

Integrated releases. Tables 5.71 and 5.72 give integrated radionuclide releases at both the WIPP site boundary and the stock well for Cases IIA(rev) and IIC(rev). (The term "integrated release" is used as defined by the EPA standard in 40 CFR Part 191, Subpart B. It means the total cumulative release over the full width of the contaminant plume for a period of 10,000 years.) The calculation is made at the site boundary and the stock well, 3.6 and 6.0 km, respectively.

The April 1989 draft SEIS reported an estimate of Case II integrated releases. Those calculations were made with the earlier, one-dimensional version of the SWIFT II code in which the width of the contaminant plume was not explicitly calculated by the code, but was approximated. Using maximum and minimum estimates of this width and concentrations of radionuclides at the stock well (concentrations at the site boundary not having been calculated), maximum and minimum estimates of the integrated releases past the stock well were made.

The Case II results reported here were made with a version of the SWIFT II code that has been updated to include lateral dispersion, species-specific diffusion, and the revised Culebra flow field. It is a fully two-dimensional code that treats the lateral spread of the contamination plume explicitly.

The integrated releases for Cases IA, IB, and IC, the expected and degraded performances of an undisturbed repository, are all zero. In Case IIA(rev), the expected performance of the disturbed repository, the resulting normalized sum of radionuclides is 1.7×10^{-6} at the WIPP site boundary. In other words, the sum of the ratios of amounts of individual radionuclides released to their regulatory-maximum amounts is less than unity, the amount permitted. (See Appendix I.1.5. The site boundary is used as an approximation to the edge of the "accessible environment," that point not having yet been defined for the WIPP.)

Case IIC(rev) uses a highly degraded set of parameters to characterize the repository-geosphere system in the case of a disturbed repository; the resulting normalized sum of radionuclides is 3.17 at the site boundary. The latter figure appears to be clearly above the regulatory limit of 1.0. However, the EPA regulations are written in terms of a probabilistic risk assessment; an apparently over-regulatory-limits figure like this has to be coupled with the probability of this extreme scenario actually occurring. The analysis of compliance with those regulations will be performed near the end of the WIPP Test Phase.

The results of the present Case II analysis are compared with those of the preliminary analysis in Table 5.73. The revised calculations at the site boundary are of the same order of magnitude as the earlier ones at the stock well, while the revised calculations at the stock well are less than the earlier ones. Examination of the individual tabulations indicates that the largest difference from the earlier results arises from a significant reduction of centerline concentrations that is directly due to using a formal two-dimensional approach. The lateral dispersion reduces the centerline concentrations by as much as a factor of 10 for Case IIA(rev).

Another difference between the present Case II analysis and the earlier one is the use of species-specific diffusion coefficients. As discussed earlier, there is a substantial difference between single- and double-porosity flow predictions, with a concentration difference of between 10 and 100 at the site boundary. This sensitivity to dual-porosity effects implies a corresponding sensitivity to free-water diffusivity. However, the species-dependent diffusivities (Appendix I, Table I.2.13) of the present analysis assumes only a maximum factor of 3.8 variation from the Case IIA value used in the draft SEIS. Therefore, the impact of nuclide-dependent diffusivities in Case IIA(rev) should be less than the variation between single- and double-porosity behavior of between 10 and 100.

The last major difference between the present Case II analysis and that of the draft SEIS is the use of the revised flow field from the recently recalibrated flow model described in Subsection 4.3.3.2. Particle travel time to the stock well is a sensitive parameter (Reeves et al., 1987), but its change in the present analysis is only 4.8 percent relative to earlier. Therefore, the change in stock-well location and Darcy

velocities due to the recalibrated model has had only relatively small impact on these results.

The Case IIC(rev) result appears to exceed the EPA standard. However, it should be remembered that the standard deals with probabilities rather than certainties (see Appendix I.1.5). The standard assumes that the DOE will summarize the results of a performance assessment as a Complementary Cumulative Distribution Function (CCDF) indicating the probability of exceeding various levels of integrated release.

No one calculation will determine whether the WIPP complies with the standards; a calculation such as is in Case IIC(rev) will be but one of perhaps a thousand that will enter into this analysis, each one with an associated probability to it. This Case IIC(rev) calculation assumes a combination of degraded parameters that was intended to represent a near-extreme set of inputs and result in as high calculated concentrations at the site boundary as thought possible consistent with currently available data (Table 5.57). This combination of input parameters has only a low probability of occurring. On the other hand, the integrated release of the expected case (Case IIA[rev]) is almost a factor of a million below the release limit. This range of results between expected and maximum credible releases suggests that most of the individual calculated integrated releases will be much smaller than that calculated for Case IIC(rev).

Nevertheless, if the degraded transport properties used in Case IIC(rev) appear to be much more probable than assumed above after experimentation in the WIPP Test Phase, engineering modifications to the waste or backfill are available that may improve the performance sufficiently to achieve compliance with the standards (see Section 6).

Table 5.71 Integrated release at WIPP-site boundary and stock well at 10,000 years, Case IIA(rev)

Radionuclide	Release limit (Ci)	WIPP-Site Boundary: Integrated release (Ci)	WIPP-Site Boundary: Release ratio (IR/RL)	Stock Well: Integrated release (Ci)	Stock Well: Release ratio (IR/RL)
Np-237	660	4.10×10^{-6}	6.21×10^{-9}		$<10^{-13}$
Pb-210	660	5.42×10^{-4}	8.22×10^{-7}	6.15×10^{-8}	$9.32<10^{-11}$
Pu-239	660		$<10^{-13}$		$<10^{-13}$
Pu-240	660		$<10^{-13}$		$<10^{-13}$
Ra-226	660	5.39×10^{-4}	8.16×10^{-7}	6.12×10^{-8}	9.28×10^{-11}
Th-229	660	5.81×10^{-9}	8.81×10^{-12}		$<10^{-13}$
Th-230	66	3.82×10^{-10}	5.78×10^{-12}		$<10^{-13}$
U-233	660	2.45×10^{-6}	3.71×10^{-9}		$<10^{-13}$
U-234	660	1.53×10^{-6}	2.31×10^{-9}		$<10^{-13}$
U-236	660	1.84×10^{-8}	2.79×10^{-11}		$<10^{-13}$
		Sum =	1.65×10^{-6}	Sum =	1.86×10^{-10}

Source: Lappin et al., 1990, to be published

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Table 5.72 Integrated release at WIPP-site boundary and stock well at 10,000 years, Case IIC(rev)

Radionuclide	Release limit (Ci)	WIPP-Site Boundary: Integrated release (Ci)	WIPP-Site Boundary: Release ratio (IR/RL)	Stock Well: Integrated release (Ci)	Stock Well: Release ratio (IR/RL)
Np-237	660	1.37×10^{1}	2.07×10^{-2}	9.11	1.38×10^{-2}
Pb-210	660	1.31×10^{1}	1.99×10^{-2}	1.18×10^{1}	1.78×10^{-2}
Pu-239	660	1.19×10^{3}	1.81	2.99×10^{1}	4.53×10^{-2}
Pu-240	660	1.93×10^{2}	2.93×10^{-1}	4.69	7.11×10^{-3}
Ra-226	660	1.36×10^{1}	2.06×10^{-2}	1.19×10^{1}	1.81×10^{-2}
Th-229	660	1.32×10^{1}	1.99×10^{-2}	6.48	9.82×10^{-3}
Th-230	66	3.59×10^{-1}	5.44×10^{-3}	1.72×10^{-1}	2.60×10^{-3}
U-233	660	5.35×10^{2}	8.10×10^{-1}	3.11×10^{2}	4.71×10^{-1}
U-234	660	1.12×10^{2}	1.70×10^{-1}	6.56×10^{1}	9.95×10^{-2}
U-236	660	1.05	1.59×10^{-3}	5.15×10^{-1}	7.80×10^{-4}
		Sum =	3.17	Sum =	6.86×10^{-1}

Source: Lappin et al., 1990, to be published

Table 5.73 Comparison of preliminary and present estimates of integrated releases

	Preliminary release ratio at stock well (IR/RL)	Revised release ratio at stock well (IR/RL)	Revised release ratio at boundary (IR/RL)
Case IIA	6.5×10^{-7} - 9.1×10^{-7}	a	a
Case IIA(rev)	a	1.9×10^{-10}	1.7×10^{-6}
Case IIB	1.7×10^{-1} - 2.7×10^{0}	a	a
Case IIC	3.2×10^{-1} - 4.9×10^{0}	a	a
Case IIC(rev)	a	7.0×10^{-1}	3.2×10^{0}
Case IID	6.6×10^{-4} - 1.2×10^{-2}	a	a

[a] Not calculated.

5.5 NO ACTION ALTERNATIVE

The No Action Alternative was included among those alternatives considered in the FEIS of 1980. The FEIS analyzed the impacts of maintaining defense TRU waste in retrievable storage for an indeterminate period. The Record of Decision on the FEIS, which was published on January 28, 1981, determined, as part of the basis for decision, that the No Action Alternative was "unacceptable." This determination was made at the time because of the potential impacts of natural, low probability events and human intrusion at storage facilities after governmental control of the site is lost.

Under the No Action Alternative, TRU waste would not be shipped to nor emplaced in the WIPP for the Test or Disposal Phases. The WIPP would be decommissioned or put to other uses as appropriate. TRU waste would continue to be generated and retrievably stored by the DOE. However, unless treated in accordance with the EPA treatment recommendations, such storage of TRU mixed waste would be in conflict with the EPA's Land Disposal Restrictions (40 CFR 268). Improvements, modifications, and/or new construction at existing DOE storage facilities would be required to safely store TRU waste. In addition, new DOE or commercial storage facilities likely would be required.

The following subsections summarize the consequences of the No Action Alternative.

5.5.1 Generator/Storage Facilities

5.5.1.1 Introduction. The FEIS and this SEIS have analyzed the environmental consequences of the No Action Alternative under several different assumptions and conditions. In general, it is estimated that if the DOE would provide effective monitoring and maintenance of storage facilities, adverse health effects for the general public would be quite small, and the principal adverse effects, also small, would be related to occupational activity at the facility. Health effects would continue at such levels for the indefinite future under the hypothesis of DOE control.

Alternatively, if the DOE were not to maintain effective control of storage facilities, it is estimated that intruders could receive substantial radiation doses, a situation that could persist for the indefinite future. Therefore, the No Action Alternative would require effective long-term institutional control to avoid such unwanted consequences.

Under the No Action Alternative, storage of newly generated TRU mixed waste would be in conflict with the RCRA Land Disposal Restrictions (40 CFR 268). Storage of mixed waste after the effective date of the Land Disposal Restrictions may be prohibited, since the Land Disposal Restrictions allow restricted waste to be stored solely to accumulate quantities necessary to facilitate proper recovery, treatment, or disposal. Capacity for treatment required by the Land Disposal Restrictions prior to disposal currently does not exist at DOE or commercial facilities. Such treatment may have significant environmental impacts and costs. For example, the EPA treatment standard for solvents requires incineration of the waste and the proposed treatment standard for radioactive lead solids would require surface deactivation or removal of radioactive lead portions followed by micro- or macro-encapsulation. Appropriate NEPA review would be required if treatment of TRU mixed waste were proposed. Regardless of whether the mixed wastes are treated to comply with the Land Disposal Restrictions, the wastes remaining would be TRU wastes and require storage and eventual disposal.

In addition, the RCRA may have major impacts upon the manner in which TRU waste which is co-contaminated with hazardous chemical waste is held in retrievable storage. As this waste increases in volume with the generation of new waste, additional retrievable storage capacity which meets stringent storage requirements would have to be provided. Additionally, as current storage containers begin to show signs of deterioration and are retrieved and repackaged (or overpacked), additional RCRA permitted storage facilities may have to be constructed. This may be appropriate to ensure that storage facilities comply with the applicable RCRA standards. The space requirements of replacement facilities at all facilities have not been estimated. However, it is likely that the space required in aboveground facilities to meet the RCRA requirements would exceed approximately 4 times the current space required for storage of TRU waste which is not co-contaminated.

5.5.1.2 **Transportation**. If the No Action Alternative were selected, there would be no transportation risk from transportation of CH TRU or RH TRU waste to the WIPP for either the Test or Disposal Phases. Shipment of newly generated TRU waste to retrievable storage facilities would continue.

5.5.1.3 **Radiological**. Under the No Action Alternative, TRU wastes would not be emplaced at the WIPP during the Test or Disposal Phases. Therefore, there would be no radiological consequences to workers or the public from such emplacement. If the No Action Alternative was selected, exposures would continue to occur at the retrievable storage facilities.

Some of the major retrievable storage facilities have completed NEPA documents which describe the effects of continued retrievable storage. The following subsections provide a synopsis of the extent of routine exposures expected at current retrievable storage facilities if no action were taken to open the WIPP. Additional exposures would be anticipated if treatment were required to comply with the RCRA Land Disposal Restrictions. This subsection describes exposures and facility modifications which would generally be representative of those expected at all retrievable storage facilities under the No Action Alternative. The reader is referred to the published environmental documents for greater detail: DOE (1988f), DOE (1987a), and DOE (1980).

Radiological Impacts - Idaho National Engineering Laboratory. The impacts at the Idaho National Engineering Laboratory of not opening the WIPP are addressed in the FEIS (DOE, 1980). TRU waste presently stored in a retrievable fashion at the Idaho National Engineering Laboratory and newly generated waste would remain in storage for an indeterminate period or be transferred to another storage facility. Methods for managing waste under this alternative were considered in detail in Appendix N of the FEIS, and are summarized below.

Subalternative 1: Leave the waste in place, as is. A cover of plywood, polyvinyl sheeting, and three feet of earth would be maintained over the waste. Monitoring and sampling would continue. Newly generated waste would be similarly stored.

Subalternative 2: Improve in-place confinement of stored waste. The confinement of the waste would be improved without relocation. Providing a barrier over the top and sides of the waste would consist of adding ten feet of compacted clay and a 3-foot cover of basalt rip-rap over the storage pads. Barriers at the bottom of the waste would include the same clay and basalt rip-rap as on top and would add a pressure-grout sealing of the sediments beneath the asphalt pad. Alternately, the waste would be immobilized in place by injecting grout into the waste and into the sediments beneath the pad.

The FEIS concluded on the basis of its risk analysis that the first two subalternatives would result in limited radiation releases in the short term and concluded that only very small releases would result in the third subalternative from either routine operation or accidents. The FEIS concluded that no environmental reasons were found why TRU waste could not be stored at the Idaho National Engineering Laboratory as it is presently for several decades or a century.

The 1980 FEIS evaluated projected accidental releases and exposures from human-caused events and natural disasters, as a result of no action or leaving waste in retrievable storage. The FEIS evaluated the impacts (radiological) of disruptive natural events of volcanic action, earthquake, dam failure, and human intrusion. The dose commitments presented in the FEIS are summarized in Table 5.74.

The FEIS concluded that over the long-term volcanic activity and human intrusion if institutional control were lost holds the greatest potential risk for long-term accidental release of radionuclides, under "as is" conditions and under "improved confinement.' The improved confinement option involved providing a barrier of 10 feet of clay and 3 feet of basalt rip-rap over the waste, as well as injecting grout into the waste and the sediments beneath the supporting asphalt pad. The conclusions of the FEIS regarding volcanic activity and its impact on the nearby population as a result of long-term storage are summarized in the following paragraphs (FEIS Appendix N should be consulted for further details).

Drawn from a study of many possible release mechanisms (DOE, 1979), Table 5.75 gives estimates of the possible radiation doses resulting from these disruptions. Natural disasters could deliver significant dose commitments (up to 90 rem to the lung) to maximally exposed individuals if the first subalternative were used; the second subalternative would reduce this dose commitment to 0.9 rem. Human intrusion could deliver much higher dose commitments to a few people in each generation, but this condition could persist for many generations. Improved confinement (subalternative 2) gives the possibility of a hundredfold-smaller individual and population dose commitments, but leaves the waste at the surface.

Radiological Impacts - Savannah River Site. An Environmental Assessment (DOE, 1988f) was prepared which discussed the impacts at the Savannah River Site of the WIPP not opening (No Action Alternative). The Savannah River Site would continue storage of retrievable and newly generated TRU waste on storage pads. The waste is contained in concrete and steel boxes, culverts, and drums. Packages placed in retrievable storage on concrete pads were covered with four feet of earth until mid-1985; currently, they are covered with tornado netting. Based on current processing rates, one additional storage pad would be needed each year until an environmentally acceptable long-term disposal option is found. Corrosion of drums, and subsequent contamination of the environment is possible over the longer-term. This alternative does not provide for the permanent disposal of TRU waste nor allow the Savannah River Site Burial Grounds to be closed according to DOE directives issued in the June 1983 Defense Waste Management Plan.

Table 5.76 provides a summary of consequences from postulated accidents at the Savannah River Site Burial Grounds. This information illustrates the potential exposures to on-site and off-site populations from leaving TRU waste in retrievable storage.

Radiological Impacts - Hanford Reservation. A FEIS was prepared in 1987 which addressed the impacts at the Hanford Reservation of not opening the WIPP (DOE, 1987a); the continued storage of radioactive TRU wastes was evaluated as the No Action Alternative. The In-Place Stabilization and Disposal Alternative was also analyzed; in this alternative the sites would be stabilized and covered with a protective barrier and marker system.

For the No Action Alternative, retrievably stored and newly generated TRU waste would continue to be retrievably stored for 20 years after generation; current packaging and storage procedures would be followed. The drums would be stored in designated

TRU waste sites and covered with soil. Monitoring, surveillance, and maintenance would continue until a recovery or disposal decision is made.

The estimated annual total-body radiation dose to the workforce at the Hanford Reservation under the No Action Alternative (continued storage) was 20 person-rem and was 60 person-rem for In-Place Stabilization and Disposal. When considering institutional controls, the off-site public would be expected to receive no radiation dose from continued storage of retrievably stored and newly generated TRU waste during routine operations. In the absence of institutional controls, however, the potential exists for adverse impacts to the "off-site" population because nothing would prevent intrusions into waste sites or use of contaminated groundwater. It was estimated (DOE, 1987a) that potential total-body doses as a result of the No Action or In-Place Stabilization and Disposal options from various accidents or human intrusion scenarios involving retrievably stored TRU waste would range from about 4×10^{-5} to 4 rem/year.

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TABLE 5.74 Summary of long-term dose commitments for leaving the stored waste in place at INEL, without additional mitigation measures[a]

Disruptive event	Whole body	Bone	Lung
Maximum individual[b] 50-year dose commitment (rem)			
Explosive volcano	6×10^{-3}	8	20
Earthquake	2×10^{-8}	2×10^{-5}	4×10^{-5}
Mackay Dam failure	3×10^{-9}	1×10^{-4}	NA[e]
Volcanic lava flow[c,d]	3×10^{-2}	50	90
Intrusion			
Ingestion	7	400	NA
Inhalation	10	500	700
Population[f,g] 50-year dose commitment (person-rem)			
Explosive volcano	40	40,000	80,000
Earthquake	1×10^{-4}	1×10^{-1}	2×10^{-1}
Mackay Dam failure	1×10^{-8}	5×10^{-4}	NA
Volcanic lava flow[c,d]	100	200,000	400,000
Intrusion			
Ingestion	70	4,000	NA
Inhalation	90	4,000	6,000

[a] Data from DOE (1980).

[b] The whole-body dose received from natural background radiation during the 50 years is about 7.5 rem.

[c] Overburden was assumed to resist lava flow as long as maintenance continued. Release was assumed to occur 100 years after implementation, when maintenance has been discounted.

[d] The dose-commitment calculations for this scenario are subject to large uncertainties.

[e] NA = not applicable.

[f] Population = 130,000 except for intrusion, where it is 10.

[g] The whole-body population dose received from the natural background radiation during the 50 years would be about 1,000,000 person-rem for the larger population and about 75 person-rem for the population affected by intrusion.

TABLE 5.75 Possible long-term consequences of storage at INEL

Release mechanism	Individual dose commitment (rem)			Population[a] dose commitment (person-rem)		
	Whole body	Bone	Lung	Whole body	Bone	Lung
Subalternative 1: Waste left as is[b]						
Volcano	0.006	8	20	40	40,000	80,000
Lava flow	0.03	50	90	100	200,000	400,000
Intrusion[c]	10	500	700	90	4,000	6,000
Subalternative 2: Improved confinement[d]						
Volcano	0.00006	0.08	0.2	0.4	400	800
Lava flow	0.0003	0.5	0.9	1	2,000	4,000
intrusion[c]	0.1	5	7	0.9	40	60

[a] Population is 130,000 for volcanic action and lava flow, 10 for human intrusion.

[b] Data from Table N-1 in Appendix N (DOE, 1980).

[c] Dose from inhalation.

[d] Data from Table N-2 in Appendix N (DOE, 1980).

TABLE 5.76 Summary of consequences from postulated accidents in the Savannah River Site Burial Ground[a]

Accident	Curies Released	Effective Dose Equivalent: On-site Population (person-rem)	Effective Dose Equivalent: Off-site Population (person-rem)	Effective Dose Equivalent: Offsite Maximum Individual (mrem)
Winds				
100 mph[b]	2.1×10^{-2}	1.6×10^{-1}	4.4×10^{0}	6.3×10^{-2}
> 150 mph[b]	4.2×10^{-2}	2.2×10^{-1}	6.3×10^{0}	7.3×10^{-2}
Tornado				
113-157 mph	2.5×10^{-2}	9.3×10^{0}	$1.6 \times 10^{+1}$	1.3×10^{-2}
158-206 mph	5.3×10^{-2}	$2.1 \times 10^{+1}$	$3.5 \times 10^{+1}$	2.7×10^{0}
Fire				
Drum in culvert	1.7×10^{0}	$9.3 \times 10^{+3}$	$2.0 \times 10^{+4}$	$4.4 \times 10^{+3}$
Drum on TRU pad	5.0×10^{-3}	$2.8 \times 10^{+1}$	$6.1 \times 10^{+1}$	$1.3 \times 10^{+1}$
Drum Rupture				
Internally induced	5.0×10^{-3}	$2.8 \times 10^{+1}$	$6.1 \times 10^{+1}$	$1.3 \times 10^{+1}$
Externally induced	5.0×10^{-5}	2.8×10^{-1}	6.1×10^{-1}	1.3×10^{-1}

[a] Estimated from the analysis of potential Burial Ground accidents (DOE, 1988f).

[b] Straight winds.

5.5.2 WIPP Site

5.5.2.1 **Biology**. Biological impacts at the WIPP from implementing a No Action alternative would be dependent upon the final status of the facility. Impacts would be similar to those identified for the proposed action if the facility were put to other uses which involved comparable levels of activities for comparable periods of time as proposed for WIPP operations.

Impacts from decommissioning and dismantling the facility would be similar to those described in the 1980 FEIS for the proposed action. Plants and animals in the area would be affected by fugitive dust, noise, and road traffic. Disturbed land would ultimately return to its natural state.

5.5.2.2 **Socioeconomics**. Decommissioning and dismantling the facility under this alternative would cost up to $400 million (estimated to be expended over five years). During this period, backfill for the mined areas, building razing, restoration of the site surface, and other closure activities associated with the physical location would occur. Operating contractor and DOE personnel would exit the area over the period.

The No Action Alternative would have a detrimental socioeconomic impact on southeastern New Mexico—particularly on Eddy County and mainly on the City of Carlsbad. During FY 1988, the jobs created or supported by the WIPP project were estimated at over 1800 in the two county region or 4.6 percent of the total regional employment (Adcock et al., 1989). Total economic activity was estimated at nearly $210 million and the annual addition to personal income at $50 million. The current level of activity (FY 1989) is approximately the same. With the No Action Alternative, these conditions would begin a downward trend in FY 1990.

Under the Proposed Action, the jobs the WIPP provides in the region would have leveled at just over 1600, with total economic activity at slightly above $160 million annually (constant 1990 dollars). The annual personal income addition caused by the WIPP Project would have been about $43 million (constant 1990 dollars).

Under the No Action alternative, the regional economy would cease to receive these positive impacts by the end of FY 1994 rather than at the end of the decommissioning in FY 2018. The No Action alternative would cause community-based economic concerns at a time when the region has not fully recovered from decreased activity in potash mining and oil and gas production. The City of Carlsbad and its environs would bear the greatest proportion of the regional loss of economic activity. Over the 24-year period, from the beginning of FY 1995 through decommissioning in FY 2018, total personal income would have increased $960 million under the Proposed Action. During the same time period, WIPP-related additional economic activity (indirect spending) would have been $3.6 billion in the region.

If the No Action alternative were chosen, after facility closure by the end of FY 1994, over $1.2 billion of federal monies would have been expended on planning, preconstruction, construction, preoperation, experimental activities, mitigation, and expenses for the closure of the WIPP.

5.5.2.3 **Land Use**. Implementing the No Action Alternative would return the currently controlled lands to their previous status. Existing mineral denials would once again be available for commercialization. A minor increase in grazing allotments on public lands would accrue to this alternative (approximately 18 cattle).

5.5.2.4 **Air Quality**. Implementing the No Action Alternative would result in temporary decline of air quality (principally TSP) due to dismantling activities. These impacts would be small and would not have long-term implications. The impacts would be similar to those that could occur during decommissioning of the WIPP in the Proposed Action.

5.5.2.5 **Cultural Resources**. Impacts from implementing the No Action Alternative would be the same as for the Proposed Action. Special precautions would be taken to preserve cultural resources.

5.5.2.6 **Water Quality**. No impacts would occur to the hydrology and water quality at the WIPP site from implementing the No Action Alternative.

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6.0 MITIGATION MEASURES

6.1 INTRODUCTION

As defined in the regulations issued by the Council on Environmental Quality (CEQ), "mitigation" includes avoiding, minimizing, rectifying, reducing, eliminating, and compensating for adverse impacts (40 CFR Part 1508.20).

The purpose of this section is to summarize mitigation measures that have been implemented, measures that are proposed, and some conceptual measures (principally waste treatment technologies) that may be proposed if the Test Phase indicates a need for such mitigation to ensure adequate long-term performance of the repository.

The FEIS in Subsection 9.6 identified several design features and construction practices that were proposed to mitigate the potential adverse effects of the WIPP project. These mitigation measures were primarily related to construction activities and included minimizing zones of construction activity, restoring areas disturbed by construction, diverting surface runoff from salt-pile areas, and controlling fugitive dust through the use of surfactants and paving in zones of major construction traffic.

Mitigation measures that have already been implemented, or are proposed, or are under consideration are discussed in SEIS Subsection 6.2. The remaining subsections evaluate mitigating measures that may be proposed, based on the results of the Test Phase, to enhance the long-term performance of the repository. These include engineering modifications and waste treatment technologies.

Engineering modifications may involve the placement of specially formulated backfill materials, grouting, and other activities intended to prevent the long-term movement of waste materials from their original location of emplacement. These modifications generally include the creation of physical barriers to the movement of waste materials. Subsection 6.3 describes engineering modifications that could be used during the Disposal Phase.

Waste treatment technologies are described in Subsection 6.4. The purpose of this subsection is to describe, in conceptual terms, the technologies that could be used to treat TRU and mixed TRU waste. The purposes of these treatments, as they relate to the WIPP, may include preparation for transportation to the WIPP in compliance with the WIPP Waste Acceptance Criteria (WAC), meeting the TRUPACT certified waste form, and/or the modification of the waste form to ensure acceptable long-term repository performance. After publication of the draft SEIS, the DOE formed an Engineering Alternatives Task Force to evaluate potential waste form treatments, facility design modification, and regulatory compliance approaches that may be evaluated during the Test Phase. Efforts are being accelerated to allow potential treated waste in the earlier bin tests.

It is not known which, if any, of the technologies presented in Subsections 6.3 and 6.4 may be proposed to ensure or enhance long-term repository performance. Decisions would be based on data generated during the Test Phase. If, for example, it is

determined through the Test Phase experimentation that gas generation could impair long-term repository performance, then gas-getter materials could be proposed as a mitigative measure. The interim performance assessment calculations would indicate whether some type of waste treatment would be needed. Thus, these subsections are intended to describe what types of technologies currently exist for mitigation, what types of problems these technologies are intended to correct, and which technologies are currently used or proposed at DOE facilities.

6.2 CONSTRUCTION, TEST AND DISPOSAL PHASES, AND TRANSPORTATION–RELATED MITIGATION MEASURES

The following mitigation measures have already been or will be implemented. Many of these measures were discussed in Subsection 9.6 of the FEIS.

Existing Facilities. The surface facilities, the shafts, and some of the underground experimentation rooms and waste disposal rooms for initial waste emplacement have been constructed. The remaining repository area remains unexcavated to prevent the premature closure of empty rooms by salt creep; it will be excavated as needed. The requirements of the Occupational Safety and Health Administration (OSHA) and Mining Safety and Health Administration (MSHA) have been closely followed. The existing surface facilities have been constructed with airlocks and controls to create negative pressures to minimize the potential for the release of hazardous or radioactive materials during operation. High-efficiency particulate air (HEPA) filters have been included in air exhaust systems to mitigate the impact of any release that might occur during normal operations or in the event of an accident.

Operations. Operations at the WIPP would involve a wide range of activities, including waste handling, operation of surface facilities, and mining operations. Measures would be incorporated into all of the activities to minimize the health and safety risks to workers and to the general public. All activities would be performed in compliance with the applicable health and safety standards and in accordance with established standard operating procedures (SOPs) contained in the "WIPP Operational Safety Requirements Administration Plan" and the "WIPP Radiation Safety Manual" (WEC, 1988a; 1988b). Personnel exposure to radiation would be governed by the as low as reasonably achievable (ALARA) principle as developed in the DOE exposure guide (DOE, 1980) and in DOE Order 5480.11. Additional mitigative measures would be developed to provide increased protection for workers and the general public. For example, potentially exposed workers would be required to wear full-face respirators if any waste package being handled contains more than 100 PE-Ci of radioactivity. A HEPA filter system is available on the underground ventilation system to reduce the amounts of radioactive material released from the WIPP to the general environment in the event of an underground release. This HEPA filter system can be activated by the underground and/or exhaust monitoring systems or manually by the Central Monitoring Room operators.

The primary operational safety concerns would be for personnel exposure to radioactive and hazardous chemical constituents during waste emplacement and retrieval (if necessary), and room stability.

Waste emplacement operations for the Test Phase would be similar to those planned for normal waste handling and would be governed by established procedures (WEC, 1988a; 1988b). Additional procedures would be developed to address operational safety during waste testing and would include the following requirements:

- Monitoring for radiation and volatile organic compounds prior to the removal of samples from the test area
- Use of appropriate personal protective equipment
- Preparation of radiation work permits for most of the tests involving actual TRU waste
- Monitoring of test activities by health physics and industrial hygiene personnel
- Review of testing procedures by the Westinghouse Radiation Safety Section.

In addition, personnel exposures would be controlled by the WIPP underground ventilation system and the use of HEPA filters on the alcove seals.

Rock stability is a concern for both operational safety and for ensuring the retrievability of the waste used in the Test Phase. The roofs of the test rooms will be rock bolted in a manner similar to the other underground openings to minimize rock instability.

Measures to ensure operational safety during waste retrieval (if necessary) would be similar to those taken during waste emplacement for the Test Phase. Gas and liquids removed from the test bins and alcoves would be monitored for radiation and volatile organic compounds before being removed from the test areas. Environmental documentation will be prepared, as appropriate, to evaluate the potential environmental impacts and risks to human health and safety.

Biology. Ecological resources have been and will continue to be protected by avoiding unnecessary damage to vegetation, wildlife, and soil by controlling traffic, minimizing the areas of disturbance, controlling runoff, and cleaning up spills. As stated in Subsection 9.6.1 of the FEIS, temporary facilities (e.g., haul roads, stockpiles, and work areas) are restored by regrading, reseeding, and fencing as construction activities are completed. Environmental monitoring programs will continue to provide early warning if the biological environment is being affected so that mitigative measures can be developed and implemented.

To study the impacts on raptors, a Cooperative Raptor Research and Management Program has been initiated jointly by the DOE, the Bureau of Land Management (BLM), and the Living Desert State Park in Carlsbad, New Mexico. As a result of this program, work schedules in field locations near nesting raptors have been modified and 10 man-made nest platforms have been placed around the WIPP site.

Socioeconomics. Socioeconomic impacts associated with the WIPP project have been reduced through the release of land in Control Zone IV for unconditional use. Among

the mineral resources released for mining were approximately 50 million tons of potash that were unavailable under the 1980 Proposed Action. Additional mitigative measures for socioeconomic impacts have previously been discussed in FEIS Subsection 9.6.6 and updated in Subsection 5.1.2 of this SEIS.

Air Quality. The air pollution control measures described in Subsection 9.6.2 of the FEIS will continue throughout operation of the WIPP. Hydrocarbon emissions are being controlled through the use of proper fuels. Dust levels were reduced by paving heavy traffic areas in the summer of 1988; dust will continue to be controlled by spraying water on temporarily disturbed areas.

Cultural Resources. Since the publication of the FEIS, two additional archaeological investigations have been performed for the WIPP. The first investigation located 40 archaeological sites in the area of the WIPP site, and the second investigation excavated and evaluated three sites that could be disturbed or destroyed by construction activities. The railroad spur was relocated to avoid potential adverse effects on one of these three sites. Knowing the locations of the archaeological sites at the WIPP is essential to being able to take the proper mitigation measures should WIPP activities necessitate disturbance of any of the sites.

Transportation. Programs have been developed to reduce the opportunities for accidents and to mitigate the effects of any accident when transporting waste to the WIPP site. (Appendices C, D, L, and M contain detailed discussions of the mitigative measures presented below).

First, the routes that the trucking contractor must follow are those preferred routes established under U.S. Department of Transportation (DOT) routing rules for highway route controlled quantities of radioactive materials in 49 CFR 177. This routing rule permits States and Indian Tribes to designate routes in accordance with DOT guidelines or an equivalent routing analysis. Interstate highways must be used in the absence of a State- or Tribal-designated route, unless a deviation is necessary.

Second, the selection qualifications and training requirements for the trucking contractor's drivers have been made part of the trucking company's management plan (Appendix M) and the contract with the trucking company. In addition to meeting the licensing stipulations in DOT regulations (49 CFR 177.825 and 391) and the Commercial Motor Vehicle Safety Act of 1986, each driver must be at least 25 years of age, have logged a minimum of 100,000 miles in a tractor-trailer combination, and have at least 2 years of uninterrupted commercial tractor-trailer driving experience during the past 5 years. Approved drivers would also undergo a driver-training program that complies with the requirements of 49 CFR 177.825, including accident or other emergency training, and sabotage avoidance traning. Two drivers would be in the tractor-trailer during transport, and one driver would remain with the tractor-trailer during stops.

Under the provisions of the trucking company's safety manual, drivers will be tested for drugs and other substance abuses on a routine and random basis. Included in the management plan is the provision for severe penalties to the drivers for failure to follow proper procedures. For example, if a driver deviates from the preferred route without authorization because of weather or other hazards, the first offense will result in

suspension without pay for two weeks. The second offense will result in immediate termination. The tight procedures and severe penalties associated with trucking operations will serve to ensure that drivers will operate their vehicles in a safe and professional manner.

A sophisticated tracking and communication system (TRANSCOM) has been developed for monitoring truck movement when transporting waste to the WIPP site. This near-real-time system will operate 24 hours per day, using navigation, telecommunication, and computer network technologies to verify that each tractor-trailer is on the specified route and following the established transportation schedule. Direct communication by mobile phone between a dispatcher and the tractor-trailer will allow updated information regarding route changes, approaching severe weather conditions, road hazards, detours, etc., to be utilized in avoiding potentially hazardous situations. This system is currently being tested with the drivers and trucking equipment.

All waste to be shipped to the WIPP will be certified to meet both the WIPP Waste Acceptance Criteria (WAC) and the Nuclear Regulatory Commission's (NRC) transportation criteria (see Appendices A and L, respectively). These criteria have been developed in part to limit the spread of contamination in the event of a breached container, thereby mitigating the effects of an accident. All DOE and contractor personnel involved in the container inspection, waste handling, certification, loading, and TRUPACT-II operations will be trained and certified in their job duties and must follow approved procedures. All activities will receive day-to-day oversight by a designated Site Certification Official and are subject to audit by the DOE.

At the heart of the safety system mitigating the effects of a potential accident are the NRC-certified Type B containers that will be used to transport TRU waste. For CH TRU waste, the TRUPACT-II received its Certificate of Compliance from the NRC on August 30, 1989. For RH TRU waste, the NuPac 72B will meet NRC testing requirements and be certified before it will be used to transport waste. The design criteria for the Type B containers have been judged by Sandia National Laboratories to be able to survive 99.5 percent of all potential accidents without a breach of the container.

The containers will be manufactured conforming to DOE design specifications and the manufacturers' quality control program for raw materials, purchased subcomponents, and fabrication and assembly. The full manufacturing process is auditable by the DOE. Following manufacture, the containers will be inspected and approved for use by the DOE, following established criteria. Each container will be inspected following established procedures before being loaded. All maintenance performed on the containers will be conducted by trained and certified personnel following approved procedures.

Under Federal and State regulations, each State, Indian Tribal, and local government is responsible for developing generic emergency response plans and for providing the first response to emergencies involving radioactive material. Through the States Training and Education Program (STEP), more than 3600 law enforcement, medical, and fire personnel along the transportation routes have been trained by DOE to date in emergency response to radioactive material shipping accidents (see Subsection 2.8).

This program provides the first emergency personnel at the accident site. It also provides the training necessary to determine the actions required to establish command and control authority at an accident scene, and to implement measures to protect life, property, and the environment.

During transportation, to increase public confidence and maintain a high level of coordination, an operator at the WIPP Central Coordination Center (CCC) will monitor incoming and outgoing shipments 24 hours per day, 7 days a week. The duties of the CCC operator will include the following:

1) Monitor the transport of the TRUPACT-II containers and the shipping casks for RH TRU waste, both loaded and empty.

2) Coordinate, as necessary, the activities of the DOE, the trucking contractor, and the drivers, in the event of breakdown or driver emergency.

3) Provide a means of emergency notification.

4) Coordinate, as necessary, with the State and local personnel who are designated first responders and with law-enforcement agencies.

5) Coordinate between the drivers and the Joint Nuclear Accident Coordinating Center for a safe haven for the shipment if necessary. (A "safe haven" is a parking area, for example, at military installations that can be used, by agreement with the U.S. Department of Defense, for TRU waste shipments.)

6) Function as a central tracing point in the event the TRANSCOM satellite-based system does not function properly.

The trucking contractor (carrier) would play a key role in mitigating potential transportation accidents or dealing with any accidents that may occur. The contractor will maintain a DOE-approved emergency-response plan, including an itemized list of the emergency equipment carried on the vehicle and will provide all tractors transporting the TRU waste with equipment to be used in the event of a transportation accident. This equipment includes a citizens' band radio, a mobile telephone, an antenna for the TRANSCOM satellite-based vehicle-tracking system, and instruments for detecting and measuring alpha, beta, and gamma radiation. The drivers of the tractor-trailers are trained in radioactive-waste transportation and emergency response, including procedures for obtaining local, State, or Federal assistance, if technical advice or emergency assistance is needed. As explained in Appendix M, two drivers will be used for each shipment in order to provide continual surveillance of the tractor-trailer. The drivers will also be trained in the use of the radiation dosimeters. They will be supplied with complete procedures for responding to the accident, including the telephone numbers of the CCC at the WIPP, the cognizant State agencies, and the telephone numbers of the DOE's regional offices of the Radiological Assistance Plan. The drivers will be given telephone numbers that can be called collect if the mobile telephone does not operate. For communication with the dispatcher of the trucking contractor, the drivers will be given 800-numbers.

While State, Tribal, and local authorities are responsible for initial response and command and control at accidents, the DOE, as owner and shipper, will be present at the scene to assess the damage, to determine whether any release of radioactive material has occurred, and to help the State and local authorities promptly inform the public about the situation. In the unlikely event that a release of radioactive material has occurred, the DOE will collect the TRU waste and any debris; decontaminate soil, vehicles, and persons as needed; reload the TRU waste into new shipping containers; and return the site of the accident to normal use.

6.3 LONG-TERM FACILITY PERFORMANCE ENGINEERING MODIFICATIONS

6.3.1 Engineering Modifications Related to Geologic Parameters

Since the FEIS was issued, geological concerns have been raised regarding the effects of mining operations on the host rock. Excavation of underground rooms at the WIPP has resulted in fracturing of the surrounding rock, creating a "disturbed rock zone" (DRZ).

The DRZ is a volume of rock adjacent to an underground excavation in which mechanical properties (e.g., elastic modulus) and hydraulic properties (e.g., permeability and degree of saturation) have been changed by the mining of that excavation. The development of a DRZ is a complex process, with the existing geologic structure (e.g., fractures, bedding, clay and anhydrite interbeds) and fluid losses due to mine ventilation interacting with the stress field developed during mining. These interactions apparently play a significant role in the development of the DRZ at the WIPP and include the following:

- strain rate dependent brittle fractures
- microfracturing in response to release of in situ fluid pressure
- possible decoupling of the ellipsoidal DRZ volume from the host rock
- shear displacements along planes of weakness
- beam buckling and flexural slip folding toward the underground opening.

The DRZ has been characterized by three approaches: visual observation, geophysical methods, and measurement of hydraulic properties. All three approaches define a DRZ extending laterally throughout the excavation and varying in thickness from the walls of the excavations from 1.0 to 5.5 yards, according to the size and age of the opening (Borns and Stormont, 1988). The larger and older excavations exhibit a greater degree of fracturing than smaller and younger excavations. With time, a DRZ is expected to develop around all underground excavations.

Although the occurrence of a DRZ is both common and expected in underground engineering, the development of a DRZ around the WIPP underground excavation was not considered in the FEIS (except indirectly, as a zone of "dilatancy"). Prior to mining the underground workings, it was expected that only a minimal amount of remedial work would be necessary to stabilize spalling and fracturing.

The short-term concerns caused by the presence of the DRZ have been personnel safety and maintenance of the underground openings. Remedial work performed has included removal of scaling material and installation of wire mesh and rock bolts.

The occurrence of fracturing within the DRZ also causes an increase in permeability (at least locally). This raises the concern that the DRZ may provide pathways for fluids to bypass tunnel and shaft seals (see Subsection 5.4.2.4). Two possible long-term mitigation measures for DRZs are discussed in the following subsections. More detailed information regarding the DRZ is presented in Lappin et al. (1989) and Borns and Stormont (1988), and basic data interpretation is presented in Appendix E.8.

6.3.1.1 Removal of the Disturbed Rock Zone at Seal Locations. Two major considerations in sealing access ways are the quality of the seal-rock interface and the nature of the DRZ near the seal. Backstress in response to salt creep in the vicinity of the relatively rigid concrete or consolidated seals should promote the healing of fractures in the disturbed rock, thereby decreasing its permeability. However, the rates and amount of permeability reduction due to the healing process are not well known. If the DRZ fractures are not healed by salt creep, they could connect the waste disposal panels with other portions of the underground facility.

The development of DRZs has already affected maintenance for several underground excavations. A primary concern during the Test Phase is to maintain a safe roof and rooms from which the retrieval of waste will not be impeded by material scaling. To that end, frequent inspections, removal of loose rock, rock bolting, wire mesh, and other techniques are employed and will continue to be employed as required.

Because the healing of the DRZ may not be fast enough, and in order to create a better match of seals to the host rock, excavation of the more transmissive portion of the DRZ around seals in accessways is being considered. Of course, a new DRZ would form around the newly excavated volume; however, the evidence is that DRZs grow slowly, so that if the seal is put into place quickly, the size and importance of the new DRZ as a possible bypass would be minimized (see Subsection 4.7.3 of Lappin et al., 1989). Studies will be conducted during the Test Phase to evaluate the growth and extent of the DRZ in such a scenario and the effectiveness of seals, given the DRZ.

Excavation of the relatively permeable Marker Bed 139 (MB139) under the seals is also being considered. However, that would not eliminate leak paths around the seals through more distant parts of MB139. If MB139 is left under the tunnels, it could be sealed with a grout whose composition would be determined using data obtained during the Test Phase. Removal of MB139 rock from under the seals may not eliminate the need to grout MB139, but would merely change the location of the grouting to more distant parts of that bed.

6.3.1.2 Grouting of the Disturbed Rock Zone Around Shafts. Excavation of the DRZ at a proposed shaft-seal location would be operationally more difficult than in a horizontal tunnel because the rock breakout and removal would either have to 1) precede the emplacement of the crushed-salt seal material and hence provide more time for the DRZ to reform or 2) proceed in parallel with the seal-material emplacement and therefore interfere with the emplacement.

An alternative under these circumstances might be to pressure-grout the DRZ in the vicinity of the proposed seal. The difficulty with this technique compared with excavation is that excavation can be guided to some extent by the appearance of the rock not yet taken out; on the other hand, the depth to which the rock should be grouted could only be guided by the ability of the disturbed rock to accept more grout.

During the Test Phase at the WIPP the DOE will continue to look for more effective means of isolating the waste disposal panels from each other and sealing the shafts to the surface.

6.3.2 Engineering Modifications Related to Hydrology and Water Quality

The FEIS considered the option of backfilling only as a means of reducing fire hazards during disposal operations (FEIS Subsection 8.4.1) and for minimizing the impacts of subsidence (FEIS Subsection 9.7.2.2). A combination of engineering modifications and geologic investigation has essentially eliminated prior concerns in these respective areas. However, studies since 1980 have raised the concern of potential brine inflow. This subsection addresses the questions of using alternative backfill materials at the WIPP as well as sealing possible routes through which brine could migrate from one part of the facility to another or to the shafts and upward to the Culebra water-bearing zone in the Rustler Formation or to the ground surface.

6.3.2.1 Emplacement of Backfill. A principal reason for backfilling WIPP disposal rooms and access tunnel systems (i.e., filling in spaces that remain open after waste has been emplaced) would be to shorten the "time for closure" of the disposal room. (The time for closure is the time required for salt creep to reduce room and waste void space to its final state. The smaller the initial void space, the quicker the entombment will be.) Rapid entombment is desirable because it may minimize brine inflow and subsequent waste dissolution, and thus may minimize contaminant releases from an inadvertent intrusion by a drillhole. By decreasing the amount of brine inflow, rapid entombment could also decrease the amount of gas generated by the corrosion of waste drums and the iron-bearing constituents of the waste.

In the FEIS, only crushed salt was considered for backfill. Since the FEIS, it has become apparent that various types of backfill may also be useful to 1) speed the entombment process and to rapidly reach final porosity within the waste areas, 2) sorb brine as it flows in, and 3) minimize the accumulation of gases.

Backfill materials under consideration include crushed salt or a 70:30 mixture of crushed salt and bentonite (SEIS Subsection 6.3.2.2). Crushed salt may be used for the access ways and either crushed salt or the salt-bentonite mixture for the disposal rooms. The need for additives that could be mixed with the backfill, such as "getters" that remove gases by sorption, would be studied in the Test Phase.

Backfilling would generally occur as follows: crushed salt from concurrent mining operations or from aboveground storage would be 1) screened to remove oversized pieces, 2) mechanically mixed with bentonite and any additives, 3) transported hydraulically or by conveyor belt to the emplacement location, and 4) emplaced around and over the

waste package. When a waste panel is completely backfilled, panel seals would be constructed to isolate the panel from the rest of the repository. Variations on these procedures might include blowing the backfill material into place to increase its in-place density and to reduce the overhead space as far as irregularities in tunnel ceilings permit or using a coarse grout to fill those spaces.

6.3.2.2 Backfill Modifications. Current plans propose that access ways, tunnels, and waste-filled rooms be completely backfilled during the Disposal Phase to improve the entombment process (Tyler et al., 1988). However, during the Test Phase, a limited backfill operation would be conducted in a way that would still allow waste retrieval operations should this be necessary. This operation would use salt and/or additives to develop operational experience, investigate engineering modifications, and evaluate the effectiveness of different types of backfill in mitigating brine inflow and gas generation (Subsection 3.1.1.4).

Reaching steady-state conditions rapidly is important because, if the contents of the room are not sufficiently dense, some of brine from the Salado or from an intruding borehole could circulate within the room, thus enhancing the potential for outward migration of radionuclides. Erosion of regions surrounding the borehole by circulating drilling fluids could also entrain radionuclides, contributing to their release. As a mitigation measure, backfilling the waste with crushed salt may help the waste attain an acceptable equilibrium state within the repository before any potential intrusion occurs.

Sorption of brine is another function of the backfill. Although recent estimates suggest that the amount of brine inflow would be small, about 43 m^3 per room in 100 years (Nowak et al., 1988), steps to control the accumulation of brine that may come into contact with waste containers are being explored. Additives to crushed-salt backfill, in particular bentonite, are under consideration because of their ability to adsorb water. As already mentioned, a mixture of 70 percent crushed salt and 30 percent bentonite (by weight) is a possible backfill material. The current estimate is that between 40 and 80 m^3 of brine per room can be sorbed by the salt-bentonite mixture, without degrading its strength or imperviousness in the compacted state (Lappin et al., 1989 Section 4.8.1).

Backfill "getters" (additives that remove gas generated by bacterial decomposition, radiolysis, and corrosion) are also under consideration as potential mitigations; however, their effectiveness is yet to be determined. Additives like calcium carbonate ($CaCO_3$) and calcium oxide (CaO) are being considered to remove carbon dioxide (CO_2) produced by bacterial decomposition. Reduction of the microbial gas-production rate might also be accomplished by storing sludges containing nitrate (NO_3^-) apart from waste containing cellulosic materials. This option might also prevent microbial nitrogen production. The addition of manganese dioxide (MnO_2) might prevent SO_4^{2-} reduction, the concomitant production of hydrogen sulfide (H_2S), and its reaction with the drums, drum-corrosion products, and iron-bearing waste to form hydrogen. Copper sulfate ($CuSO_4$) might corrode the steel drums and the iron-bearing waste without producing hydrogen (Lappin et al., 1989). The effectiveness of these getters in controlling gas in the disposal rooms would be a matter of continuing study in the Test Phase.

6.3.2.3 Emplacement of Plugs and Seals. The FEIS recognized the need to plug all remaining holes and shafts when the WIPP was filled and was being decommissioned (FEIS Subsection 8.11.3). However, although it mentioned backfilling the waste disposal rooms (FEIS Subsection 8.4.1), it did not discuss possible seals. Current plans are still to seal all holes and shafts in order to eliminate, as much as possible, the pathways through which waste material might migrate from the repository. The DOE also proposes a number of seals to isolate the different parts of the underground facility from each other and from the shafts (Stormont, 1988; see also Appendix E.9).

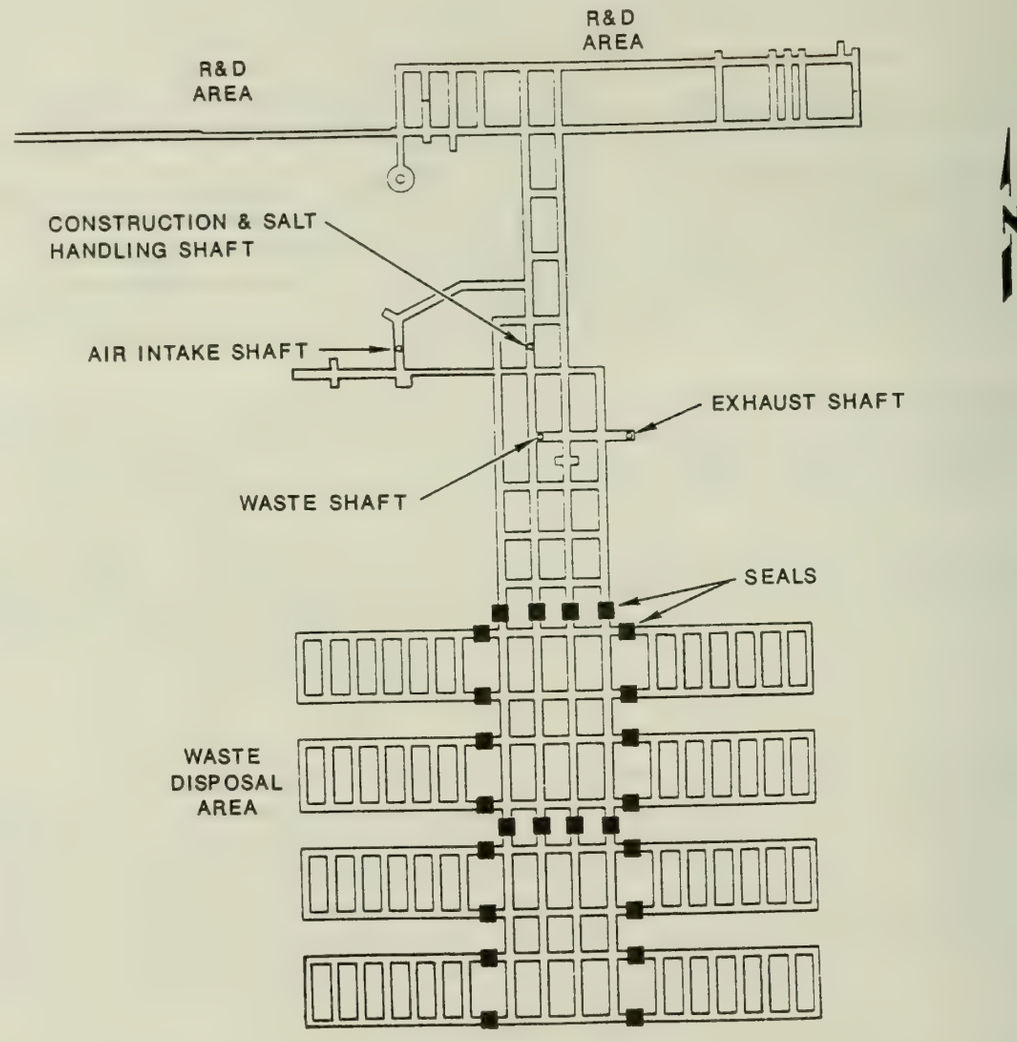
Tunnel Seals. Tunnels would be sealed after waste emplacement at the locations shown in Figure 6.1. The portion of the drift that is at the seal location would be filled with reconsolidated crushed salt, possibly in the form of blocks (Figure 6.2). The salt would be retained by end caps, but these end caps are not expected to maintain their integrity over the long term, being there only to keep the salt in place until tunnel closure consolidates it to its final density (Stormont, 1988).

Fractures in MB139, a 3-ft-thick interbed 3 feet below the tunnel floor, consisting primarily of anhydrite, may be filled with an anhydrite-compatible seal material such as a crushed salt-based grout, in order to keep it from being a bypass around the seal. Thus both the tunnel and MB139 would be sealed at each seal-system location.

Seals would be emplaced after each panel of rooms or interval of access tunnels behind the specified location has been filled with waste and backfill material. As a final action, when the WIPP is full and about to be decommissioned, tunnels outside (just north of) the final seal system would be backfilled with crushed salt until the entire underground facility, except for the shafts, has been filled. Seal systems would then be emplaced in the shafts.

Shaft Seals. Shaft-seal systems would be emplaced in each of the four WIPP shafts in order to keep these shafts from being conduits for the release of waste materials to the Culebra or the ground surface. The primary, long-term shaft seal would consist of a section of crushed salt or salt blocks in the lower part of the shaft. This material should be kept in its natural state of dryness, so that when it is fully consolidated as the surrounding salt closes in, its properties would be as similar as possible to those of the surrounding Salado salt. To protect the primary seal material from seeps from above, composite seals such as shown in Figure 6.3 would be emplaced midway to the top of the Salado and at the Salado-Rustler interface. In addition, salt-bentonite layers would be laid where the shaft intersects anhydrite beds. All other intervals in between would be filled with salt. In the Rustler, a rather complex set of concrete and salt-bentonite sections is being considered to block off that formation's numerous water-bearing beds (Figure 6.4). These composite seals are not primary barriers, nor is the upper salt section in the Salado. Since the Rustler is at a lower lithostatic pressure, salt creep and shaft closure cannot be counted on to ensure full reconsolidation in the Rustler Formation (Stormont, 1988).

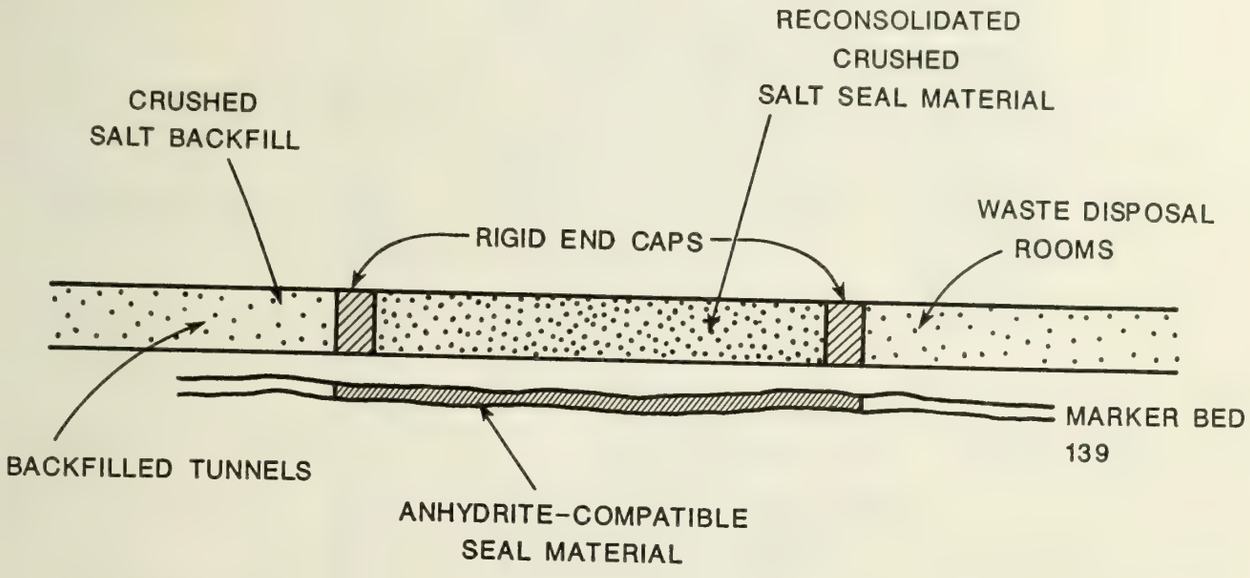
Shaft-seal systems would be emplaced after the underground facility is sealed and backfilled. Emplacements would begin at the bottom of the shaft and work upward to the surface; the shaft liner would be removed as work progresses upward.



NOT TO SCALE

REF: STORMONT, 1988.

FIGURE 6.1
TENTATIVE LOCATIONS OF PANEL SEALS



REF: LAPPIN et al., 1989.

FIGURE 6.2
SCHEMATIC OF TUNNEL SEAL

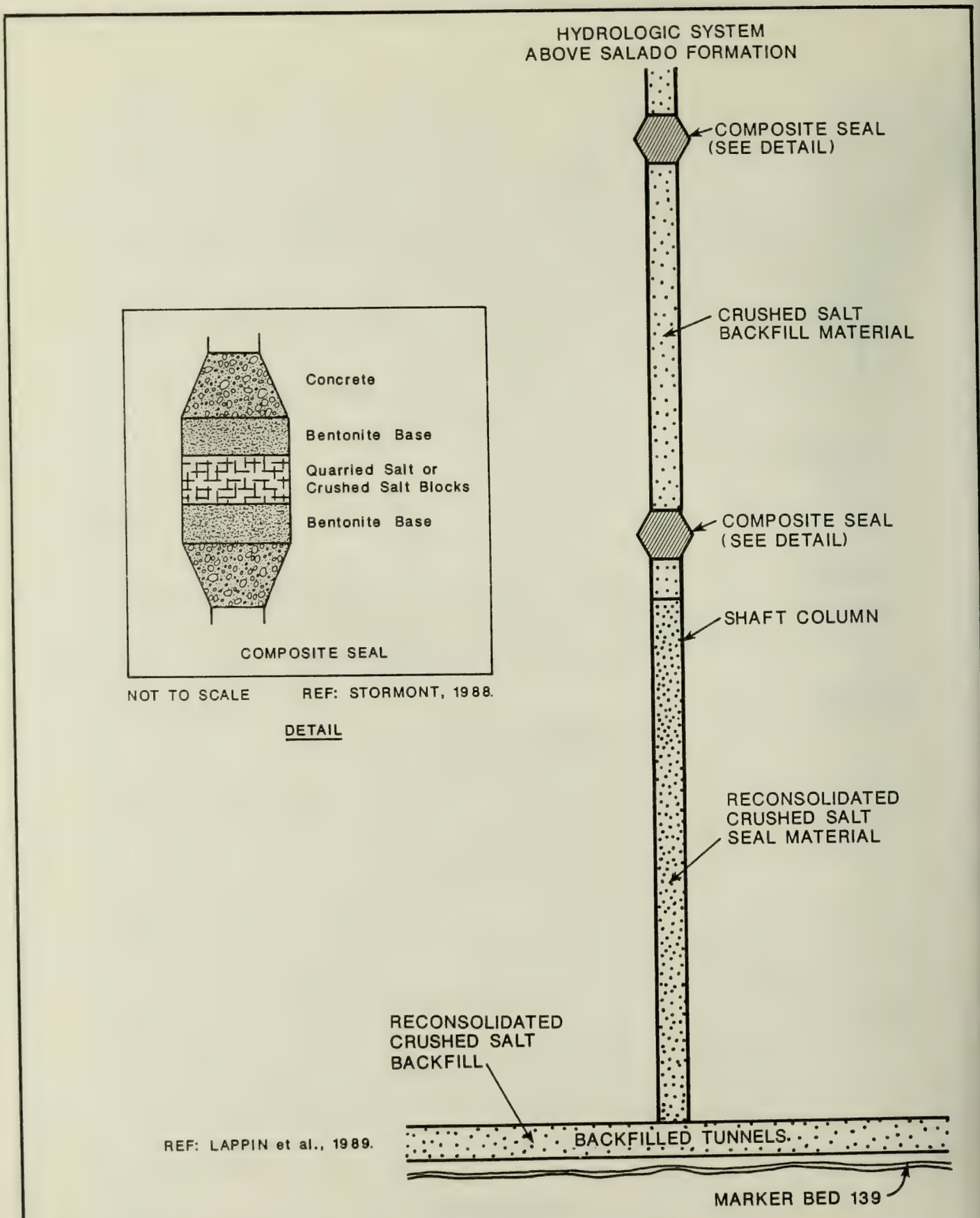
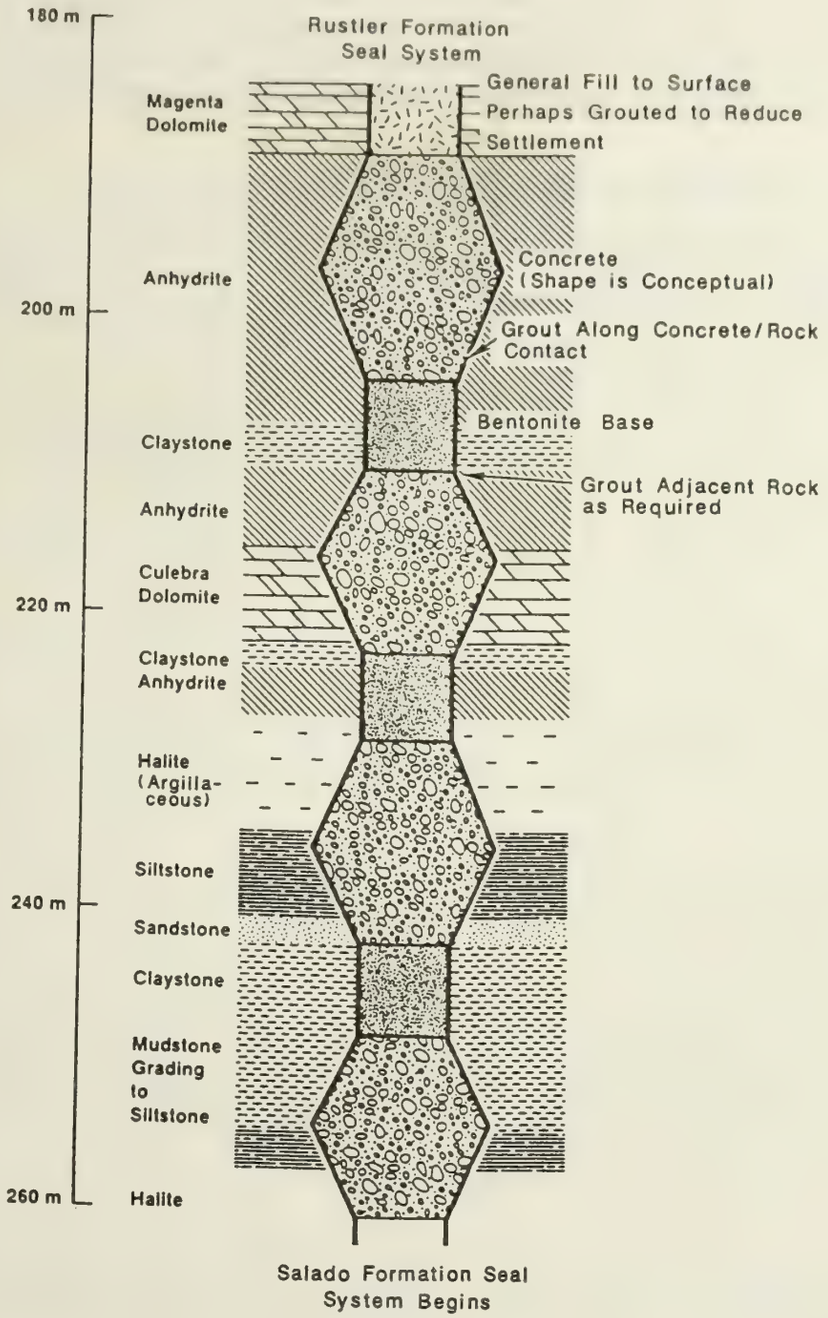


FIGURE 6.3
SCHEMATIC OF SHAFT SEAL SYSTEM IN THE SALADO FORMATION



REF: STORMONT, 1988.

FIGURE 6.4
SCHEMATIC OF SHAFT SEAL SYSTEM IN THE RUSTLER FORMATION

Variations in the shaft and tunnel seal systems are limited by the requirement of long-term effectiveness. It is for this reason that crushed salt is the primary component material in the seals described above: on reconsolidation, this material should approach the properties of the in situ rock salt. The physical form of this salt and the manner of its emplacement, however, remain open to study and future decision. The choices now evident are poured-and-tamped material or precompressed salt blocks.

6.4 MITIGATION BY WASTE TREATMENT

This subsection summarizes the development of current DOE waste treatment technologies, emphasizing those developed since the FEIS, and discusses how various treatments (e.g., incineration, immobilization, and compaction) could provide potential benefits at the WIPP. Recent waste treatment developments in private industry are also addressed. Information on some low-level-waste treatment systems is included to indicate that the technologies are developed to the point of use in the processing of radioactive waste, if not specifically TRU waste. Information on low-level-waste processing systems is included because both low-level and TRU waste processing systems must be built to meet stringent emission standards and to minimize operating personnel exposure. TRU waste (specifically plutonium) processing systems are generally constructed with an additional confinement barrier, but the processing hardware is frequently the same.

Subsection 6.4.1 briefly describes the physical effects that waste treatment can provide. If during or at the conclusion of the Test Phase it is determined that additional processing would be beneficial, one or more of these technologies could be used to enhance long-term performance. The following subsections contain a qualitative discussion of the projected benefits of immobilization, incineration, and compaction.

Two general waste treatment methods for TRU waste (incineration and immobilization) were discussed in Subsection 5.3 and Appendix F of the FEIS. Since the preparation of the FEIS, several waste treatment methodologies (such as grouting, cementation, and use of absorbents) have been developed and implemented at various DOE facilities. The treatments tend to be unique for each waste generator, because each facility has different waste forms. In general, however, all waste treatment practices tend to reduce the volume and leachability of the waste. The potential need for treatment results from a combination of regulatory and storage capacity needs and WIPP disposal-site restrictions such as the WIPP (WAC) (Subsection 2.3 and Appendix A).

6.4.1 Waste Treatment Technologies

Waste treatment influences gas generation, repository void volume, and the solubility of radionuclides and heavy metals. This subsection discusses these three phenomena and describes how they are affected by various treatment technologies.

Waste can generate gases by the biological (microbial) degradation of any organic materials present, by the corrosion of metal waste and the metal containers themselves, and by radiolysis of the waste. The estimated time periods associated with these gas generation mechanisms are discussed in Subsection 5.4. Corrosion and biological gas generation processes at the WIPP would be dependent on the availability of oxygen and/or brine (Molecke, 1979). Therefore, any waste treatment that reduces the void

space in the repository would minimize air and brine quantities and thus gas generation. Soluble radionuclides and heavy metals are subject to transport with the brine. Immobilized radionuclides and heavy metals in stable waste forms remain in the waste and are not subject to brine-transport mechanisms. Waste forms that limit the leaching of radionuclides from the waste or decrease the solubility of the radionuclides and hazardous heavy metals reduce the potential transport of the radionuclides and metals from the repository.

The following subsections indicate that immobilization, incineration, and compaction have the potential to reduce the rate of gas formation and metal solubilities to varying degrees. The desirability of changes to the WAC to require treatment of waste for disposal at the WIPP would be considered in a new supplemental EIS to be prepared prior to a decision to proceed with the Disposal Phase.

6.4.1.1 Immobilization Technologies. Appendix F of the FEIS addressed 11 immobilization processes for treating TRU waste. The discussion that follows updates the FEIS to reflect recent advances and DOE activity in immobilization technologies.

The potential benefits of TRU waste immobilization, in general, include the following:

- Reduced repository void volume. Waste solidified in cement or grout would have a lower void fraction. Room closure would be speeded, thus retarding brine inflow.

- Reduced gas generation. By retarding brine inflow and oxygen access, the rate of gas generation from drum corrosion would be reduced. Also, limiting brine/and oxygen access may retard gas generation from biodegradation of organics.

- Leach resistance. The immobilized TRU waste would be resistant to leaching because of reduced surface area and brine exclusion.

Cements and Grouts. Liquid wastes can be solidified by mixing with cement and grout formulations. Particulate solid waste can be treated similarly. Inorganic waste solidification systems have employed portland cement or similar material. Variations have consisted of such combinations as cement with fly ash, lime with fly ash, cement with sodium silicate, and lime with sodium silicate. The use of specific hydrocarbon additives allows the solidification of soils highly contaminated with oils, greases, and various other organic chemicals (Sawyer, 1988).

Radioactive mixed wastes and solid residues that have been effectively treated by cement-based immobilization include ion-exchange resins, evaporator bottoms, filter media, sludges, slags, incinerator ash, calcines, shredded metals, shredded combustibles, oils and grease, biodigester underflows, various organics, and acid-digester residues (Dole, 1985).

TRU waste solidified with cement offers the advantage that plutonium compounds tend to remain insoluble in the resulting alkaline medium (Schneider and Lederbrink, 1982). Mobile in-drum cement-solidification systems have been successfully tested on various

liquid and solid low-level and TRU waste in the Federal Republic of Germany (Brunner and Christ, 1985).

The DOE has TRU waste cementation systems at the Rocky Flats Plant and Los Alamos National Laboratory. In addition, TRU waste cementation systems are proposed for the DOE facilities at the Hanford Reservation, Oak Ridge National Laboratory, and Savannah River Site (Looper and Charlesworth, 1988; Greenhalgh, et al., 1988).

Clay. The adsorption of radioactive waste by clays requires additional treatment to prevent desorption and leaching of the waste. With the exception of the use of clays as a supplement to cement-immobilization systems at the Hanford Reservation Grout Treatment Facility and the Mound Tritiated Water Solidification System, clay immobilization is not presently in use at DOE facilities.

Pellets. The process, with its enhanced waste concentration, was developed at the Mound Laboratory, where liquid TRU waste was immobilized in portland cement and pressed into 1-inch-diameter pellets. Although this technology was demonstrated in 1982, no further development was done, and the plant was dismantled in 1987.

Salt Cake. The Savannah River Saltstone and Saltcrete operations are the sole locations where low-level waste nitrate salts are solidified. These operations use a portland cement treatment technology (Dole, 1985).

Since immobilization in cement does not chemically alter the organic waste, this technology is not expected to affect long-term gas generation from biological and radiolytic sources. However, it could be expected that the grout would exclude air and retard the entry of brine into the waste, thus retarding gas formation. In particular, the reduced void volume and retarded brine inflow would be expected to retard gas generation from corrosion. The high pH of cemented waste tends to reduce the solubility of radionuclides and heavy metals. Stable immobilization agents should provide the benefits of reduced void volume, reduced heavy-metal and radionuclide solubilities, and lower gas generation rates.

Bitumen (Asphalts). The mixing of particulate waste with hot asphalt produces a solid matrix when the asphalt cools and hardens. When wet waste is mixed with the hot asphalt, the solid particles are coated by the asphalt matrix as the water is evaporated (Klein, 1983; Mattus et al., 1988). By 1985, this method was being utilized in nine U.S. commercial power reactor plants (Jolley and Rodgers, 1987). It is not in current use at DOE facilities.

Plastic Materials (polymers). Organic solidification and encapsulation systems use a wide variety of "thermosetting" monomers, prepolymers, and resins that are hardened by using accelerators after mixing with liquid waste. The effect is microencapsulation of the waste material since direct chemical interaction between the polymer and the waste does not occur. There are no known polymer solidification systems currently in operation at DOE facilities.

Glass Immobilization. Vitrification involves melting particulate material with borosilicate compounds to form a glass solid that is resistant to leaching. Appendix F of the FEIS

discussed four immobilization techniques that involve melting of the waste: glass (solution), glass (encapsulation), ceramics, and slag. The only current activities for melted waste deal with vitrification or glassification.

The vitrification of high-level liquid waste from fuel reprocessing has been developed at the Pacific Northwest Laboratories (Holton et al., 1988). This demonstration is of limited value to the TRU waste management program because the stored TRU waste and much of the newly generated TRU waste is solid. The liquid waste processing systems developed for the high-level waste program have not addressed the handling problems associated with solid waste streams.

A second application for waste vitrification has been demonstrated at the Mound Laboratory (Klingler and Armstrong, 1986). A commercially available glass-melting furnace has been used to demonstrate applicability to the incineration-vitrification of low-level waste. However, this system has shown reliability problems with material handling systems. Vitrification technology is not considered adequately developed for current application to TRU waste. However, development continues on vitrification of solid materials, so this immobilization technique may become available in the future (Peterson et al., 1988).

6.4.1.2 Incineration Technologies. The incineration of radioactive waste was practiced as early as 1949 for the purpose of reducing the volume of the very low-level, combustible trash resulting from the operation of radioactive material handling systems. Later, other incinerators were built to separate the combustible material from waste contaminated with fissionable isotopes and thereby facilitate the recovery of these valuable materials. Operationally, incineration burns off the combustible constituents of the waste (e.g., cloth, wood, and plastic), leaving an inorganic ash. Since very few radioactive isotopes of concern are volatile, the radioactivity is concentrated in the ash. In an ash form, the concentrated radioactivity is easily immobilized.

Incineration is generally understood to be an effective, but costly, volume-reduction treatment for waste. A cost study of volume reduction at a nuclear power station estimated the cost of a waste compactor to be $275,000 (escalated to 1988 dollars), while a comparable incinerator for the application was estimated to cost $10.95 million (1988 dollars) (Trigilio, 1981). In that study, the compactor was estimated to reduce waste volumes by a factor of 2 and the incinerator reduced volumes by a factor of 16.

Radioactive waste incinerators use the same technology as trash and hazardous waste incinerators. The waste is injected into a hot chamber, where oxygen is added at a controlled rate to create a hot oxidizing environment. In this hot environment, the combustible materials are oxidized to gaseous products, mostly carbon dioxide and water. However, the offgas-cleanup systems on radioactive waste incinerators are very different from those of trash and hazardous waste incinerators. Multiple, highly efficient, and redundant components in the offgas system prevent the particulate (nonvolatile radioactive) material from being carried out of the stack with the combustion gases. In addition, the operators of radioactive waste incinerators take additional precautions to keep dust and ash contained in the system.

Since the preparation of the FEIS, there has been considerable development in radioactive waste incineration technology. The effect has been the development and subsequent abandonment of several incineration concepts and the application and production-scale use of others. Acid digestion, the agitated hearth incinerator, the cyclone drum incinerator, the molten-salt incinerator, and slagging-pyrolysis incineration have not found acceptance in the waste management industry.

Recognition of the hazardous chemical constituents of radioactive mixed waste has caused the operators of existing and proposed incinerators to also consider that aspect of the waste. The U.S. Environmental Protection Agency (EPA) has designated incineration as the "Best Demonstrated Available Technology" (BDAT) for treatment of certain chlorinated solvent wastes which are subject to RCRA Land Disposal Restrictions. Some of these constituents are contaminants in waste that may be disposed of at the WIPP. Treatment by incineration therefore may be required by RCRA Land Disposal Restrictions for some TRU waste.

The DOE has developed and operated a number of radioactive TRU waste incinerators. The Los Alamos National Laboratory Controlled Air Incinerator was constructed in 1976 to demonstrate TRU waste incineration and is now being modified to facilitate routine operation (Vavruska et al., 1989). At the Idaho National Engineering Laboratory, the Process Experimental Pilot Plant has been constructed as a research and development facility whose mission, in part, was to study processing of uncertifiable stored TRU waste. A fissionable material recovery incinerator is being constructed at the Oak Ridge National Laboratory and another is under design for the Savannah River Site. (Starr, 1988; Looper and Charlesworth, 1988).

Low-level-waste incineration facilities are being considered at the Los Alamos, Lawrence Livermore, and Oak Ridge National Laboratories; the Savannah River Site; and the DOE Pantex facility (DOE, undated; Vavruska et al., 1989; Looper, 1989; Stockton, R. and Burkhard, B., 1988).

The potential benefits of incinerating TRU waste include the following:

- Volume reduction. The combustible fraction of the waste would be reduced to a small fraction of the original volume and could result in improved space utilization and reduced transportation requirements. The benefit of the reduced waste disposal space would be a reduced probability that the waste in the repository would be intercepted in an intrusion scenario.

- Destruction of organics. Hazardous organic constituents would be destroyed.

- Reduced gas generation. Gas generation by the biological degradation of cellulosic materials would be reduced or eliminated. The gas generation by radiolysis would be reduced because of the removal of some gas generating constituents. The reduced void volume and the reduced number of waste drums would lead to reduced gas generation from corrosion, provided the material is repacked into a smaller number of drums.

- Reduced repository void volume. Waste processed through incinerators and subsequently solidified would have a very low void fraction. Combustible material would be removed, and noncombustible fractions would be encapsulated in the resulting grout.

- Leach resistance. The immobilized incinerator ash would be leach resistant. However, oxidation of the metallic compounds would tend to convert them to a more soluble form, which is an undesirable characteristic.

6.4.1.3 Compaction Technologies. Compaction or supercompaction is a method of volume reduction that can be applied to compressible waste. Compaction clearly reduces the void volume in compressible TRU waste.

An evaluation of this technology at the Rocky Flats Plant gave projected volume-reduction factors (original volume divided by final volume) of 2.6 for metals and 6.8 for combustibles (Barthel, 1988).

At the Idaho National Engineering Laboratory, the Waste Experimental Reduction Facility (WERF) is a 200-ton box compactor limited to low-level dry radioactive waste. A proposal is being evaluated for the possible future addition of a 5,000-ton supercompactor for low-level waste (Gillins and Larsen, 1987). At the Rocky Flats Plant, a Supercompaction and Repackaging Facility is due to start up in the spring of 1990. That facility, being prepared to support waste-volume-reduction efforts, would include a 2,200-ton drum supercompactor for low-level waste (Barthel, 1988). A mid-1985 survey of commercial nuclear power plants revealed that 74 compactors were in operation (Jolley and Rodgers, 1987).

6.4.2 Effects of Waste Treatment

Several DOE facilities are evaluating waste treatment and/or installing waste treatment systems for a number of site-specific reasons. During the WIPP Test Phase, the DOE would determine whether disposal-related waste treatment should be proposed as a requirement for disposal of waste at the WIPP. If waste treatment is made a requirement of the WIPP WAC, these in-progress treatment systems could provide some treated waste for the WIPP while other needed facilities are being constructed.

Qualitatively, the benefits of the improved waste forms are summarized in Table 6.1. This table shows waste treatment to provide mitigative effects, although some technologies provide greater benefits than others.

A scenario discussed in Subsection 5.4.2.6 postulates a release of material from the WIPP due to inadvertent drilling through the emplaced waste while seeking oil or gas. Waste treatment would reduce the consequences of the intrusion. If the waste is immobilized in long-lived agents, the availability of radionuclides and hazardous chemicals would be reduced, resulting in a smaller release. Gas generation from immobilized waste could be retarded, but it is not currently possible to quantitatively estimate long-term benefits from this treatment.

Regarding compaction (Weart, 1989), on the positive side, compaction would--

- Decrease the permeability of the waste (except for its metallic contents) and hence the amount of brine that has access to the waste. Dissolution of its radioactive constituents would be hindered and corrosion of the iron and aluminum in the waste and its containers would slow the generation of gases, though not decrease their total amounts.

- In removing free volume, speed the closure of the tunnel and shaft seals.

On the neutral side, compaction would not--

- Alter the effective radionuclide solubility.

- Change the amount of cellulosic and other organic materials from which bacterial action generates gases.

- Decrease the amounts of metals available from which corrosion-induced gases are generated. On the other hand, it might increase corrosion-generated gases if drums are compacted whole and repacked in other drums.

- Decrease the amount of radiolytic gas. Indeed, it might increase the rate by bringing materials closer together.

On the negative side, compaction would--

- Complicate some possible engineering modifications of waste. In particular, grouting to fill void spaces in drums would be more difficult. It is not clear, however, that it would improve the long-term performance of the WIPP appreciably (Weart, 1989).

If the waste is incinerated, there are three possible effects:

1) Gas generation from the biological decomposition of cellulosic materials would not occur. The biological gas generation potential is estimated to be somewhat less than half of the total gas generation potential, which includes gas generation from radiolysis and corrosion. The long-term benefit of the reduced gas generation would be studied during the Test Phase.

2) Treatment of the waste by incineration includes immobilization of the ash. The resulting mitigative effects are then the same as for immobilization of the waste without incineration with the added benefit of a smaller final volume and the removal of volatile organic materials and compounds.

3) Hazardous organic chemicals would not be released because they would have been oxidized and destroyed.

TABLE 6.1 Summarized qualitative description of waste treatment benefits

Parameters	Waste treatment method and benefits			
	Immobilization of sludges or grouting of sludges	Incineration with ash immobilization	Compaction	Comments
Radiolytic gas generation	Increases gases from solidification agent (small effect)[b]	Eliminates radiolysis of organics[a] Increases gases from solidification agent (small effect)[b]	May increase gas due to compacted form[b]	
Biological gas generation	Retards generation by limiting brine and oxygen access[a]	Eliminates organic degradation[a]	Retards generation by limiting brine and oxygen access[a] Does not change the amount of organic material available	
Corrosion gas generation	Retards generation by limiting brine and oxygen access[a]	Retards generation by limiting brine and oxygen access[a] Reduces generation by reducing the number of waste drums[a]	Retards generation by limiting brine and oxygen access[a] Does not decrease amount of metal available Increases generation if drums are compacted whole[b]	
Void volume	Reduces void volume by filling voids with grout[a]	Reduces voids because of cemented ash[a]	Reduces voids by compaction[a]	Reduced void volume reduces gas generation
Radionuclide and heavy-metal solubility	Retards dissolution by limiting brine access[a] Reduces solubility in alkaline media[a]	Retards dissolution by limiting brine access[a] Reduces solubility in alkaline media[a] Increases solubility from high oxidation state[b]	Retards dissolution by limiting brine access[a] Does not alter effective solubility	

TABLE 6.1 Concluded

Parameters	Waste treatment method and benefits			
	Immobilization of sludges or grouting of sludges	Incineration with ash immobilization	Compaction	Comments
Other effects	Retards dissolution of hazardous organics by limiting brine access[a]	Eliminates hazardous organics prior to emplacement[a] The reduced volume makes room penetration less likely[a]	Retards dissolution of hazardous organics by limiting brine access[a] Complicate some possible engineering modifications of waste Speed closure of the tunnel and draft seals[a]	Hazardous-organics release is dependent on degree of immobilization and effects of biological degradation

[a] Results in improved long-term waste immobilization.
[b] Results in degraded long-term waste immobilization.

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7.0 UNAVOIDABLE ADVERSE IMPACTS

The unavoidable adverse impacts accruing to the WIPP project have not changed substantially from those envisioned in Section 10 of the FEIS (DOE, 1980). This subsection identifies the changes in the unavoidable adverse impacts of the WIPP project that would result from changes in the Proposed Action since 1980.

7.1 CONSTRUCTION

There have been some minor changes in the unavoidable adverse impacts associated with construction activities at the WIPP site in southeastern New Mexico since the issuance of the FEIS in 1980. These changes were made primarily as a result of an effort by the DOE to modify and simplify the scope of the WIPP facilities in an attempt to reduce construction costs. This cost-reduction program was developed in 1982. Another modification proposed since the 1980 FEIS, but not yet implemented, was the upgrade of site security facilities. The impacts of this change are also discussed here as a change since the issuance of the FEIS.

7.1.1 Upgrade of Site Security Facilities

The DOE Exclusive Use Area at the WIPP site currently encompasses 640 acres. The DOE proposes to expand this area to 1,454 acres. This area would be fenced to increase the security of the facility once it begins receiving TRU waste. As a result, the grazing of domesticated animals would be prohibited within this increased area. The maximum number of cattle that could be affected by the increased grazing exclusion is estimated to be approximately 18 in any one year. This impact would continue until the WIPP site is decommissioned.

The surface soils would be affected during the construction of the fences. By following recommended fence-installation procedures, this impact would be minimized. When the fences are in place and grazing has been prohibited, the vegetation normally used for forage will survive and provide some measure of stability to the soil.

During the construction of the fences, air quality may be affected from the clearing of land and from the use of construction equipment, which generates air pollutants. These types of impacts were considered in the FEIS and found not to be significant for the construction of the WIPP surface facilities. In comparison, the security upgrade construction is very minor.

As described in Subsection 7.1.2 of the FEIS, there are no threatened or endangered animal species in the expanded security area. Endangered species have been identified in the WIPP vicinity; however, the expanded security area does not contain their critical habitat. Movement across the fence by deer and antelope is possible. No effects on wildlife would be expected.

Appendix H.1 of the FEIS identified three major areas of archaeological site concentrations that were located at the WIPP site. None of the sites was judged to be significant or eligible for nomination to the National Register of Historic Places. Although no mitigation is necessary, construction crews will be closely supervised during installation of the fence so that nearby sites will not be inadvertently disturbed.

7.1.2 Cost-Reduction Program

The cost-reduction program of 1982 led to the combination and elimination of buildings, modification of the aboveground salt handling logistics, and the reduction in overall site features. The combination and elimination of buildings and reduction of overall site features reduced effects on the terrain by reducing the amount of caliche and cut-and-fill material that would have been required.

Modification of the aboveground salt handling logistics resulted in the creation of two mined-rock piles instead of one. The revised design includes the pile created during the Site and Preliminary Design Validation Program. A second pile was created during full-facility construction and continues to receive mined rock.

Combining and eliminating buildings and reducing the area occupied by the facilities reduced adverse impacts on site vegetation. About 80 acres that would have been cleared under the original design remain undisturbed; however, the creation of a second mined-rock pile had some adverse impacts on vegetation. Although the total volume of mined rock (mainly salt) to be stored on the surface was decreased, the dispersion of salt and other mined-rock particles will probably affect a larger area. In addition, the amount of soil sterilized by surface storage of the mined rock will not be significantly reduced. However, soils will be sterilized at two separate locations instead of one. Subsection 5.1.1 discusses the expected impacts of the mined-rock piles on vegetation.

The reduction in size of the overall site features reduced the magnitude of adverse impacts on wildlife. However, the use of trucks to transport the waste rock on the surface, instead of a conveyor system, increased noise levels and caused increased disturbance of avian and faunal species locally. Subsection 5.1.1 discusses the expected impacts on wildlife from both the past construction and the proposed operation of the WIPP.

Under the current design for the WIPP, 1,454 acres for the DOE Exclusive Use Area will be excluded from domestic animal grazing by fencing and used as a secured area. This is an increase above the 640 acres proposed in the 1980 FEIS.

The two-county population increases predicted in the FEIS were reduced by the cost-reduction plan. The total population change for the operations period was an increase of about 700 persons instead of the 1,000-person increase predicted in the FEIS. This reduction resulted in fewer demands on existing community services and community resources. A discussion of the socioeconomic impacts of both the past construction and the proposed operation of the WIPP is presented in Subsection 5.1.2.

7.2 OPERATION

The expected unavoidable adverse impacts of operating the WIPP at the Los Medanos site in southeastern New Mexico have changed little since the issuance of the FEIS in 1980. The only areas where changes have occurred result from efforts to upgrade site security and reduce costs by simplifying and reducing the scope of the WIPP. The following paragraphs describe the impacts of these changes during the Disposal Phase at the WIPP.

During the Disposal Phase of the WIPP project, 1,454 acres of land will remain unavailable for grazing. The impact of this removal is discussed in Subsection 7.1.1; a maximum of approximately 18 cattle will be precluded from grazing during the Test and Disposal Phases.

The mined-rock pile created during full-facility construction will grow and become a more obvious feature of the landscape as additional waste rooms are mined in advance of waste emplacement. The pile will ultimately cover about 12 acres to a maximum height of about 75 feet. The mined-rock pile from the Site and Preliminary Design Validation program covers 8 acres to a maximum height of about 25 feet. Rain falling on the mined-rock piles will continue to dissolve some salt and will sterilize the soil under the pile and in the surrounding berm. Dispersion of the salt and other mined-rock particulates by wind may cause minor adverse impacts on the biota. A discussion of these impacts is presented in Subsection 5.1.1. Subsection 6.2 provides a discussion of measures that have been implemented since the issuance of the FEIS to help mitigate the potential adverse impacts of the WIPP project.

Development of the WIPP will prohibit the future recovery of potash-bearing sylvite and langbeinite, and hydrocarbons (crude oil, natural gas, and distillate) that occur in strata above and below the repository, respectively. The 1987 modification of the Consultation and Cooperation Agreement between the DOE and the State of New Mexico states:

> The DOE will not permit subsurface mining,, drilling, or resource exploration unrelated to the WIPP Project on the WIPP site during facility construction, operation, or after decommissioning. This prohibition also precludes slant drilling under the site from within or from outside the site.

This restriction applies to the 16 sections of land within the WIPP site land withdrawal boundary (Figure 2.2a). However, the economic impacts of this restriction will be reduced by the unconditional release of Control Zone IV (Figure 2.2), which will allow resource recovery in the area between the boundaries of Control Zone IV and the WIPP site land withdrawal. Nearly three-fourths of the langbeinite reserves (the most important potash within the site) and more than two-thirds of the total potash reserves are now available, and more than half of the hydrocarbons within the site can be recovered by vertical drilling in Control Zone IV.

Operation of the WIPP would release some radioactivity (Subsection 5.2.3). The estimated committed effective dose equivalent would be about 0.06 mrem (about 0.06 percent of annual natural background radiation) for a hypothetical individual living at the

point of maximum air concentration beyond the WIPP boundary. The transportation of TRU waste to the WIPP would expose people near the transportation routes to radiation. A hypothetical person living near the highway or railroad as every waste shipment passes could receive a maximum annual dose equivalent of 2.6 mrem (about 2.6 percent of the dose received from natural background radiation.)

7.3 IMPACTS AFTER DECOMMISSIONING

No new long-term, unavoidable adverse impacts have been identified for the WIPP project since the 1980 FEIS. The area disturbed during construction and operation of the WIPP would probably always show some slight sign of previous activities despite efforts to return the WIPP site to as close to its original condition as possible. TRU waste would be emplaced underground only after compliance with applicable regulations is demonstrated. Therefore, there would be no unacceptable long term radiological or chemical impacts.

7.4 COMPARISON OF ALTERNATIVES

The alternative to conduct the bin-scale tests at a facility other than the WIPP and to delay the receipt of TRU waste at the WIPP (Alternative Action) until compliance with the applicable standards has been demonstrated would result in unavoidable adverse impacts similar to those for the Proposed Action. The major difference would be the impacts resulting from conducting the bin-scale tests at a facility other than the WIPP underground facilities. These minor impacts would consist of short-term effects on land use, noise levels, and air quality at the facility selected for the bin-scale tests. The unavoidable adverse impacts of operation of the WIPP after the bin-scale tests would be essentially the same as those for the Proposed Action.

The No Action Alternative would result in some unavoidable adverse impacts, especially if the WIPP were put to other uses. However, as there has been no decision concerning other potential uses, the adverse impacts can not be determined. Any other use of the WIPP would require appropriate NEPA review. Some slight sign of previous activities would probably be noticeable if the facility were decommissioned.

Implementation of the No Action Alternative may require construction and operation of treatment facilities for the TRU waste containing hazardous chemicals that are subject to the Land Disposal Restrictions of the RCRA. Construction and Operation of these facilities would result in some unavoidable adverse impacts.

REFERENCES FOR SECTION 7

DOE (U.S. Department of Energy), 1980. Final Environmental Impact Statement, Waste Isolation Pilot Plant, DOE/EIS-0026, Washington DC.

8.0 SHORT-TERM USES AND LONG-TERM PRODUCTIVITY

The impacts of the WIPP project on the short-term uses and long-term productivity of the resources involved would be essentially the same as those described in the FEIS (DOE, 1980).

Use of the WIPP site in southeastern New Mexico for a permanent TRU waste repository would prohibit the extraction of mineral and hydrocarbon resources. However, over two-thirds of the total potash reserves previously denied would become available by allowing resource recovery in Control Zone IV of the WIPP site. More than one-half of the hydrocarbon resources within the original WIPP site could be recovered by vertical drilling in Control Zone IV as a result of its unconditional release. Mining or directional drilling from Control Zone IV of the rest of the mineral and hydrocarbon resources (i.e., those within the inner zones of the WIPP site) would be prohibited. After decommissioning, the WIPP site would be restored by recontouring, grading, seeding, and other methods to return it to its natural condition.

Conducting bin-scale tests at an existing DOE facility would have a negligible impact on any resources involved. The short-term uses and long-term productivity of the land and associated resources at existing DOE facilities are already controlled and somewhat restricted by the DOE.

The No Action Alternative would result in some impact to short-term use and long-term productivity of resources at the WIPP site, especially if the WIPP were put to other uses. There has been no decision concerning other potential uses so the adverse impacts can not be determined. Any other use of the WIPP would require appropriate NEPA review.

Decommissioning of the WIPP facility as part of the No Action Alternative would release all of the denied mineral and hydrocarbon resources for recovery. The site would be restored to as close to its natural condition as possible.

Implementation of the No Action Alternative may require construction and operation of treatment facilities for the TRU waste containing hazardous chemicals that are subject to the Land Disposal Restrictions of the RCRA. Construction and operation of these facilities would result in some impacts to short-term use and long-term productivity of resources.

REFERENCES FOR SECTION 8

DOE (U.S. Department of Energy), 1980. Final Environmental Impact Statement, Waste Isolation Pilot Plant, DOE/EIS-0026, Washington, D.C.

9.0 IRREVERSIBLE AND IRRETRIEVABLE COMMITMENTS OF RESOURCES

The irreversible and irretrievable commitments of resources associated with the phased development of the WIPP have not changed substantially from those presented in Section 11 of the FEIS (DOE, 1980). This section identifies the minor changes in these resource commitments that would result from changes in the phased development of the WIPP.

9.1 CONSTRUCTION

The surface facilities and a portion of the underground facilities have been constructed at the WIPP, and the building materials (e.g., concrete and lumber), water, electricity, and fuels (e.g., propane and diesel fuel) required for the construction have been expended. The amounts of these resources that would be required for construction were estimated in Subsection 11.3 of the FEIS and are probably somewhat greater than the amounts actually used. The cost reduction program of 1982 (DOE, 1982) (SEIS Subsection 7.1) reduced the construction of surface facilities at the WIPP and thereby decreased the consumption of the resources; however, the shortened WIPP construction schedule may have temporarily intensified the demand for the necessary resources (DOE, 1982).

The alternative to the Proposed Action would involve construction of a specially designed, aboveground facility for the performance of bin-scale tests at a location other than the WIPP underground facilities. This construction would require the consumption of building materials, water, electricity and fuels. The amounts of these resources that would be required have not been estimated, but these amounts would be very minor in comparison to those used for construction of the WIPP facilities. The effects of these resource requirements on local or regional resource availabilities would depend on the specific site chosen for the aboveground bin-scale tests.

9.2 OPERATION

Operation of the WIPP during both the Test and Disposal Phases would require the consumption of water, electricity, and fuels (e.g., gasoline and diesel fuels). In addition, the transportation of TRU waste to the WIPP would require the use of diesel fuel for trucks and/or trains. The amounts of these resources that would be required for operation of the WIPP were estimated in Subsection 11.4 of the FEIS and are not expected to have changed substantially since 1980. However, the amount of diesel fuel required for TRU waste transportation would depend on the locations of the specific DOE facilities that would ship waste to the WIPP and the transportation modes and routes to be used. It is anticipated that these resource requirements would be substantially less than local or regional availabilities of these resources.

The performance of bin-scale tests at an existing DOE facility other than the WIPP underground repository would also require the consumption of water, electricity, and fuels. These resource requirements would be very minor in comparison to those for operation of the WIPP and would have little impact on local or regional resource availabilities depending on the specific location of the facility chosen for the tests.

Throughout operation of the WIPP, the 1,454 acres of land within the proposed DOE Exclusive Use Area would not be available for uses other than those designated by the DOE. After decommissioning of the WIPP, this land would be returned to as close to its original condition as possible and would be available for restricted uses such as grazing. Land uses such as potash mining and oil and gas exploration would always be prohibited within the boundaries of the WIPP site (16 sections or 10,240 acres of land); however, the release of Control Zone IV for unrestricted use allows recovery of more than two-thirds of the total potash reserves and more than one-half of the total oil and gas resources within the original WIPP site (John et al., 1978; Keesey, 1979).

The performance of bin-scale tests at an existing DOE facility other than the WIPP underground repository would have a negligible impact on land use and resource recovery. Activities within existing DOE facilities are already controlled or restricted depending on the specific facility chosen for the tests. Performing alcove-scale tests at the WIPP would require additional water, electricity, and fuels; however, the consumption for these resources would be very small and substantially far less than their regional availability. No additional land would be required.

The No Action Alternative would result in some irreversible and irretrievable commitment of resources, especially if the WIPP were put to other uses. There has been no decision concerning other potential uses so the adverse impacts can not be determined. Any other use of the WIPP would require appropriate NEPA review. Decommissioning the WIPP would also require the use of water, electricity, and fuels.

Implementation of the No Action Alternative may require construction and operation of treatment facilities for the TRU waste containing hazardous chemicals that are subject to the Land Disposal Restrictions of the RCRA. Construction and Operation of these facilities would result in irreversible and irretrievable commitments of resources.

REFERENCES FOR SECTION 9

DOE (U.S. Department of Energy), 1982. "Review of the Environmental Analysis for the Cost Reduction Proposal for the WIPP Project," letter dated July 8, 1982, William A. Vaughn (Assistant Secretary, Environmental Protection, Safety, and Emergency Preparedness) to Herman E. Roser (Assistant Secretary for Defense Programs).

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10.0 ENVIRONMENTAL REGULATORY REQUIREMENTS AND OVERSIGHT ORGANIZATIONS

This section updates Section 14 of the FEIS regarding the environmental regulatory requirements, such as permits, approvals, and consultations, that are required for the WIPP. It also includes a discussion of new DOE policy directions being instituted to enhance protection of public health and safety and the environment with respect to DOE activities. In addition, details are provided on several agencies and organizations having oversight responsibilities regarding the environmental performance of the WIPP since the FEIS was published. Subsection 10.3 provides an updated discussion of oversight entities and responsibilities.

The regulatory changes, additions, or updates in this section include the following:

- Applicability of the Resource Conservation and Recovery Act (RCRA) to the hazardous chemical constituents of transuranic (TRU) mixed waste
- Update regarding the National Emission Standards for Hazardous Air Pollutants (NESHAPs) for radionuclides under the Clean Air Act
- Update on compliance with the Federal Land Policy and Management Act (FLPMA)
- Discussion of the Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes
- Updates regarding U.S. Nuclear Regulatory Commission (NRC) certification of TRUPACT-II and transportation regulations
- Discussion of compliance with DOE Order 5481.1B, Safety Analysis and Review System.

10.1 REGULATORY COMPLIANCE COMMITMENT AND STRATEGY

In commenting on the draft SEIS, many members of the public expressed concern that the DOE would not comply, or would not comply adequately, with various environmental laws and regulations applicable to the WIPP. Much of the focus of concern was on compliance with the EPA radiation protection standards for the management and disposal of TRU waste and compliance with the RCRA.

The DOE is committed as a matter of policy to compliance with all applicable local, State, and Federal laws and regulations intended to protect the public health and safety and the environment. These include, but are not limited to the RCRA, the Clean Air Act,

the Clean Water Act, the Safe Drinking Water Act, the National Environmental Policy Act (NEPA), the National Historic Preservation Act, the FLPMA, the Hazardous Materials Transportation Act, the Endangered Species Act, attendant Federal regulations, and parallel State laws and regulations. They also include regulations of the NRC pertaining to transportation of radioactive materials, although the WIPP is not formally regulated or licensed by the NRC.

Secretary of Energy James D. Watkins, on June 27, 1989, announced a series of 10 initiatives to demonstrate the DOE's commitment to comply with environmental requirements and protection of the public health and safety. The plan reset DOE priorities to reflect environment, safety and health as more heavily weighted than production.

The 10 initiatives to help restore the DOE's credibility include:

1) Beginning negotiations with States hosting DOE nuclear facilities to allow direct access and to improve monitoring capabilities

2) Modifying the criteria for awarding contractor fees to reflect increased emphasis on environment, safety, and health

3) Establishing independent "tiger teams" to conduct environmental compliance assessments

4) Improving the way in which DOE complies with NEPA documentation requirements and coordinating NEPA activities with governors of States which host DOE facilities

5) Establishing a new management team within the DOE Office of Defense Programs to emphasize safety over production

6) Strengthening the environment, safety, and health technical capabilities of line managers within the DOE organizational structure

7) Appointing an independent panel to help restructure DOE's epidemiology programs, including creating a National Academy of Sciences oversight committee to oversee epidemiology research requests

8) Establishing a comprehensive epidemiological data repository containing information on past and present DOE workers that can be used by any qualified researcher

9) Requiring that milestones to achieve full compliance with Occupational Safety and Health Administration standards be included in the Defense Facilities Modernization Five-Year Plan

10) Accelerating cleanup of DOE facilities through the allocation of an additional $300 million for Fiscal Year 1990 activities consistent with the Environmental Restoration and Waste Management Five-Year Plan.

Included in the 10-point announcement was a decision that the WIPP would not open until the Secretary deems it safe and other key non-DOE reviewers are satisfied. A "blue-ribbon panel" of recognized experts from industry, academia, and government has been formed to review current plans for demonstrating WIPP's technical and operational adequacy. The National Academy of Sciences has been asked to advise DOE on the adequacy of the geotechnical test program.

The overall environmental regulatory compliance strategy for the WIPP will reflect the new 10-point program and other emerging DOE environmental policies. It will also abide by the numerous DOE Orders and policy directives derived from the Atomic Energy Act that supplement and clarify other applicable Federal environmental laws and regulations. This strategy includes:

- Complying with the NEPA and Council on Environmental Quality (CEQ) regulations. The DOE is completing this SEIS and will issue a subsequent Record of Decision. As noted elsewhere in this SEIS, during the Test Phase, the need for additional NEPA documentation based on the new information obtained would be determined and prepared, if appropriate. In addition, the DOE will issue another SEIS at the conclusion of the Test Phase and prior to a decision to proceed to the Disposal Phase.

- Complying with the U.S. Environmental Protection Agency (EPA) environmental radiation protection standards in Subparts A and B of 40 CFR Part 191. The DOE will comply with Subpart A upon receipt of waste at the WIPP for the Test Phase. The DOE has prepared a plan to demonstrate compliance with the assurance requirements of 40 CFR 191.14 and will demonstrate compliance with Subpart B, including the assurance requirements, prior to proceeding with the Disposal Phase. The DOE has prepared plans to demonstrate compliance with Subpart B of the EPA standards (40 CFR 191) (DOE, 1989a; Bertram-Howery and Hunter, 1989). The DOE is also preparing a performance assessment methodology report and finalizing its Test Plan for collecting the data to be used in conducting the performance assessment.

- Complying with the Resource Conservation and Recovery Act, as amended. A RCRA no migration variance petition as provided by 40 CFR 268.6 was submitted to the EPA in March 1989. Additional information was provided in October 1989. The EPA is currently evaluating the petition.

- Finalizing the WIPP Final Safety Analysis Report (FSAR). The FSAR is being prepared consistent with DOE Order 5481.1B. The FSAR is a systematic analysis of the potential hazards associated with WIPP operations. Mitigating measures are considered. Analyses conducted for the June 1989 draft FSAR have been incorporated into this SEIS. This information is complete enough to allow a reasoned choice among the alternatives addressed in this SEIS.

- Complying with the FLPMA. The DOE has submitted an application for an administrative withdrawal of WIPP site acreage. The DOE's preference, however, is for a legislative withdrawal.

10.2 PERMITS AND APPROVALS

Tables 10.1 and 10.2 list active permits, approvals, and notifications obtained or provided in compliance with Federal and State requirements. This information was obtained from the Annual Site Environmental Monitoring Report for the Waste Isolation Pilot Plant for calendar year 1988 (DOE, 1989b) and was updated with more recent information. Permits obtained that are no longer in effect are listed in the same document (DOE, 1988b). Since publication of the FEIS in 1980, it has become necessary to address compliance with several additional regulatory or approval requirements. These are summarized in this subsection, along with updates or changes to requirements that existed in 1980.

10.2.1 Resource Conservation and Recovery Act of 1976

When the FEIS was prepared, it was believed that the RCRA, 42 U.S.C. 6901 et seq., did not apply to radioactive waste contaminated with RCRA-regulated hazardous chemicals (mixed waste). On July 3, 1986 (51 FR 24504), the EPA published a notice of its determination that wastes containing both hazardous and radioactive contaminants were subject to regulation under RCRA. In the same notice, the EPA notified the States that they must obtain authority from the EPA to regulate the hazardous constituents of "radioactive mixed waste" in order to obtain or retain authorization to administer and enforce a RCRA Subtitle C hazardous waste program.

Following the 1986 EPA determination, and after further deliberation, the DOE issued a final "by-product material" interpretative rule on May 1, 1987, (10 CFR Part 962; 52 FR 15937) in which the DOE concluded that the term "by-product material" refers only to the radioactive components of nuclear waste streams. This interpretation terminated several years of uncertainty over the meaning of the RCRA exclusion of "by-product material" in Section 1004(27) of the RCRA. The hazardous chemical components of DOE-generated mixed waste are subject to regulation under the RCRA.

The DOE is committed to compliance by the WIPP with all applicable RCRA requirements including those pertaining to transportation, waste handling, and waste emplacement of radioactive mixed waste. The four major RCRA compliance requirements pertinent to the WIPP are briefly summarized below.

Interim Status Authorization. The RCRA provides that owners or operators of facilities "in existence" on the effective date of statutory or regulatory changes (under RCRA) making the facility subject to permitting requirements can qualify for interim status by 1) filing the "preliminary notification" of hazardous waste management activity required by Section 3010(a) and 2) applying for a RCRA permit by submitting Part A of the permit application. The effect of having interim status is that owners or operators are "treated as having been issued such permit until such time as final administrative disposition of such application is made" [RCRA Section 3005(e)(1)(C)].

TABLE 10.1 Active Federal permits, approvals, and notifications

Granting agency	Types of permits, approvals, and notifications	Permit number	Date granted	Date expires
Department of the Interior, Bureau of Land Management	Land use permit to dispose of construction debris	NM-067-LUP-237	02/09/87	02/09/90
Department of the Interior, Bureau of Land Management	Land use permit for placement of raptor platforms	NM-060-LUP-235	09/12/86	09/12/89[a]
Department of the Interior, Bureau of Land Management	Approval to drill two new test wells on existing pads at P-1 and P-2	NA[b]	09/18/86	NA
Department of the Interior, Bureau of Land Management	Right-of-way for water pipeline	NM53809	08/24/83	NA
Department of the Interior, Bureau of Land Management	Right-of-way for north access road	NM55676	08/24/83	NA
Department of the Interior, Bureau of Land Management	Right-of-way for railroad	NM55699	09/27/83	NA
Department of the Interior, Bureau of Land Management	Right-of-way for dosimetry and aerosol sampling sites	NM63136	07/03/86	NA
Department of the Interior, Bureau of Land Management	Right-of-way for seven subsidence monuments	NM65801	11/07/86	NA

[a] Permit reapplied for recently.
[b] NA = Not applicable.

TABLE 10.1 Concluded

Granting agency	Types of permits, approvals, and notifications	Permit number	Date granted	Date expires
U.S. Environmental Protection Agency	Notification of two underground fuel storage tanks at the WIPP	NA	04/15/86	NA
U.S. Environmental Protection Agency	Acknowledgment of Notification of Hazardous Waste Activity (TRUPACT Assembly Facility)	NM 982283566	10/87	NA
U.S. Environmental Protection Agency	Acknowledgment of Notification of Hazardous Waste Activity (WIPP)	NM 4890139088	01/88	NA
U.S. Environmental Protection Agency	Submission of Part A RCRA Permit Application	NA	07/88 (applied)	NA

[a] Permit reapplied for recently.

[b] NA = Not applicable.

Table 10.2 Active State permits and approvals

Granting agency	Type of permit or approval	Permit number	Date granted	Date expired
New Mexico Environmental Improvement Division	Open burning permit to train fire control crews[a]	NA[b]	03/17/89 (extension)	03/17/90
New Mexico Environmental Improvement Division	Food or purveyor permit for cafeteria	4CA08CARRS184A	10/10/86	NA
New Mexico Department of Game and Fish	Permit to collect biological samples	1775	02/15/89	12/31/89[a]
New Mexico Department of Game and Fish	Concurrence that construction of the WIPP will have no significant adverse impact upon threatened or endangered species	NA	04/07/80	NA
New Mexico Commissioner of Public Lands	Right-of-way for high-volume air sampler	RW-22789	10/03/85	10/03/2020
New Mexico Department of Finance and Administration, Planning Division, Historic Preservation Bureau	Concurrence that the archaeological resources protection plan is adequate to mitigate adverse impacts upon cultural resources resulting from construction of the full WIPP	NA	07/25/83	NA
New Mexico Environmental Improvement Division	Submission of Part A RCRA Permit Application	NA	07/88 (applied)	NA

[a] Permit reapplied for recently.

[b] NA = Not applicable.

The WIPP qualifies as an "existing facility" for the purpose of being eligible for interim status under RCRA. The DOE has taken all necessary steps to qualify the WIPP as an interim status facility by 1) submitting a preliminary notification and Part A of the RCRA permit application to the New Mexico Environmental Improvement Division (EID) and to the EPA Region VI, and 2) taking necessary steps to ensure that the WIPP complies with the interim status regulatory requirements of 40 CFR Part 265.

Section 74-4-3.2 of the New Mexico Hazardous Waste Act was amended during the 1989 legislative session to eliminate the specific exemption of the WIPP from the requirements of the Act. Thus, the State currently has authority to regulate mixed waste at the WIPP under State law and submitted an application to the EPA for the requisite authority over radioactive mixed waste on July 19, 1989, in accordance with the EPA July 3, 1986, notification. This authority will become part of the State's EPA-authorized RCRA program when the application is approved by the EPA and the WIPP will have interim status under RCRA.

Waste Characterization. The RCRA regulations in 40 CFR 265.13 require that anyone who treats, stores, or disposes of hazardous waste must obtain a "detailed chemical and physical analysis of a representative sample of the waste." In addition, the land disposal restriction requirements in 40 CFR 268.7 set forth waste analysis requirements to determine if waste to be land disposed meets the treatment standards. Precise waste characterization data exist for the TRU waste currently being generated. However, waste characterization for TRU waste that has been in storage for a number of years ("old" waste) has relied solely on knowledge of the process from which the waste was derived as provided for in 40 CFR 262.11(c)(2). The characterization of old waste through knowledge of process is preferred by the DOE because opening great numbers of stored containers to collect and analyze "representative samples" of TRU waste would pose a radiological risk to workers.

Land Disposal Restrictions. The 1984 Hazardous and Solid Waste Amendments (HSWA) include a prohibition on the land disposal of hazardous waste containing certain listed chemical characteristics (RCRA Section 3004[d]). "Land disposal" is defined under the amendments to include any waste placement in land management units, including salt dome formations, salt bed formations, underground mines, and caves. Thus, the WIPP qualifies as a land disposal unit. The HSWA requires that levels or methods of treatment (treatment standards) be established for groups of chemical and toxic waste that would diminish a waste's toxicity or reduce the likelihood that a waste's hazardous constituents would migrate in the environment. The amendments prohibit the land disposal of listed waste not meeting the treatment standards according to a schedule of statutory deadlines ending May 8, 1990. Storage of mixed waste after the effective date of the Land Disposal Restrictions may be prohibited, since the Land Disposal Restrictions allow restricted waste to be stored solely to accumulate quantities necessary to facilitate proper recovery, treatment, or disposal. Since some TRU mixed waste contains chemical constituents subject to the land disposal restrictions, some portion of the TRU mixed waste intended for emplacement at the WIPP is or will be subject to these restrictions. Several options are available under the regulations for accommodating these restrictions.

The DOE is currently pursuing a "no migration" variance from the land disposal restrictions. EPA regulations allow the disposal of hazardous waste that does not meet the treatment standards if a petitioner can demonstrate to the EPA "to a reasonable degree of certainty, that there will be no migration of hazardous constituents from the disposal unit . . . for as long as the wastes remain hazardous." "No migration" variance petitions to allow the land disposal of prohibited waste are governed by 40 CFR 268.6.

The DOE submitted a petition for a no migration variance to EPA headquarters in March, 1989. The petition was prepared in accordance with an EPA draft guidance document entitled "No Migration" Variances to the Hazardous Waste Land Disposal Prohibitions: A Guidance Manual for Petitioners (EPA, 1988). This guidance manual includes a "Checklist of Information Needs" to assist the petitioner in providing a complete document.

This no migration petition is intended to cover all current and future restricted waste that would be emplaced in the WIPP. Future changes in regulations and policies, as well as new waste information and data, will be evaluated by DOE in light of the land disposal restrictions and those revisions or modifications will be submitted to the appropriate regulatory agencies as necessary.

After a review process and prior to making a final decision on the petition, the EPA will publish a notice of its proposed decision in the Federal Register. The notice will discuss the EPA's technical basis for the decision and provide opportunity for public comment.

Granting of a no-migration variance by the EPA would mean that DOE defense program facilities could emplace radioactive mixed waste in the WIPP that would otherwise be prohibited from land disposal. If the no-migration variance is not granted, the DOE will consider other ways to comply with the Land Disposal Restrictions. These might include treating waste in accordance with existing land disposal restriction standards or proposing alternative approaches in accordance with established EPA procedures. The DOE could also examine the desirability of performing tests with TRU waste not covered by the Land Disposal Restrictions.

Final RCRA Permitting. Since 1981, the EPA has promulgated technical and performance standards for "conventional" hazardous treatment, storage, and disposal units: containers, tanks, surface impoundments, waste piles, land treatment units, landfills, incinerators, and underground injection wells. The EPA refers to hazardous waste management technologies not covered by the standards in 40 CFR Parts 264 and 265 as "miscellaneous units" for which RCRA permits could not be obtained until recently. In order to fill the gap between regulated and unregulated units and to allow the permitting of new and existing units not covered by existing regulations, the EPA adopted 40 CFR Part 264, Subpart X on December 10, 1987 (52 FR 46946).

The WIPP qualifies as a "miscellaneous unit" under the definition in 40 CFR 260.10 in that it is not one of the conventional units. Thus, ultimately, the WIPP will be permitted under RCRA as a hazardous waste management "miscellaneous unit" under Subpart X. Part B of the RCRA permit application will be submitted to the State of New Mexico once the State is authorized to regulate Subpart X waste management units.

Again, it is the intention of the DOE to comply fully with all applicable RCRA requirements.

10.2.2 Clean Air Act

The EPA is charged with regulating hazardous air pollutants under Section 112 of the Clean Air Act [42 U.S.C. 7412(b)(1)(B)]. The Administrator of the EPA signed a final rule on October 31, 1989, establishing revised NESHAPs for radionuclides. This rule establishes additional monitoring and reporting requirements for DOE facilities and sets the standard at 10 mrem/year effective dose equivalent to any member of the public.

The DOE is currently preparing a NESHAP notice of anticipated facility start-up to file with the EPA.

10.2.3 Federal Land Policy and Management Act

The 10,240 acres occupied by the WIPP site are now public lands under the jurisdiction of the U.S. Bureau of Land Management (BLM). The DOE conducted the Site and Preliminary Design Validation (SPDV) phase of the WIPP project and proceeded with full construction under two successive administrative land withdrawals: Public Land Order 6232, effective March 30, 1982; and Public Land Order 6403, effective June 29, 1983. These land withdrawals were necessary to protect the geologic integrity of the site while proceeding with site validation investigations and construction. However, the withdrawals do not permit receipt and storage of TRU or TRU mixed waste.

In order to allow the WIPP to receive TRU waste for experimentation and operational demonstration purposes, bills were introduced in the first session of the 100th Congress in the House of Representatives and the Senate. The proposed legislation, cited as the "WIPP Land Withdrawal Act of 1987," would have resulted in a permanent transfer of the WIPP site lands from the U.S. Department of the Interior (DOI) to the DOE. The Congress adjourned before a bill could be enacted.

Legislative withdrawal was again pursued in the 101st Congress and is supported by the DOE as the preferred mechanism for withdrawal of WIPP site lands. However, the DOE has also filed an application with the BLM requesting an administrative modification to the existing land withdrawal of the WIPP site acreage. The modifications requested are:

- To change the purpose of the withdrawal from construction of the WIPP to conducting a Test Phase by DOE using radioactive and mixed waste and to protect the lands pending a legislative withdrawal
- To delete that portion of the Public Land Order which prohibits the use of the withdrawn lands for the transportation, storage, or burial of radioactive waste
- To increase the DOE Exclusive Use Area from 640 acres to 1,453.9 to conform that area to DOE security requirements

- To extend the term of the withdrawal through June 1997 to provide sufficient time to conduct the test program and to retrieve the waste if necessary.

Administrative land withdrawals by the Secretary of the Interior are authorized and limited by Section 204 of the FLPMA of 1976 (43 U.S.C. Section 1714). "Withdrawal" is defined in Section 103(j) of the FLPMA as withholding of Federal land in order to (among other things) limit activities on the land, reserve the area for a particular public purpose or program, or transfer jurisdiction from one agency to another.

While a legislative withdrawal of the WIPP land would be a permanent withdrawal, the FLPMA authorizes the Secretary of the Interior to withdraw 5,000 acres or more for an initial period not to exceed 20 years, subject to renewal. The Secretary of the Interior must notify the House of Representatives and the Senate of the withdrawal no later than the date it is to become effective. Under FLPMA, the Congress may terminate the withdrawal by adopting a concurrent resolution disapproving the withdrawal.

Within 90 days of notifying the Congress of an administrative withdrawal of the type required for the WIPP, the DOI must submit a number of information items to the appropriate Congressional committees including, but not limited to:

- A clear explanation of the proposed use of the land
- An inventory of current natural resources, uses, and values of the land to be withdrawn as well as adjacent land uses and values
- An analysis of any conflicting or incompatible uses
- A discussion of consultations made or to be made with other Federal agencies, State and local governments, and other "appropriate" individuals and groups
- The time and place of hearings and other opportunities for public involvement
- A detailed report on mineral values.

The DOE is seeking the administrative modification as a course of action parallel to a preferred legislative withdrawal. The DOE will cooperate fully with the DOI with regard to the procedural and administrative requirements of FLPMA.

The BLM participated as a cooperating agency in the preparation of this SEIS in accordance with the CEQ regulations in 40 CFR 1501.6.

The BLM published a notice in the Federal Register upon receipt of the DOE's withdrawal application, attended public hearings on the draft SEIS, and participated in the preparation of this final SEIS. After considering the purpose and need for the withdrawal, the environmental impacts, public comments, and the DOE's Record of Decision, the BLM will submit findings and recommendations to the Secretary of the Interior. The Secretary will make a decision to issue a withdrawal modification through

a Public Land Order or deny the application. In either case, a notice would be published in the Federal Register.

10.2.4 Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level, and Transuranic Radioactive Waste (40 CFR Part 191)

The authority of the EPA to establish radiation protection standards that apply to disposal activities and defense activities under the jurisdiction of the DOE derives from the Atomic Energy Act of 1954 (42 U.S.C. 7101 et seq.), Reorganization Plan Number 3 of 1970. The 40 CFR Part 191 Standards were proposed on December 29, 1982 (47 FR 58196) and made final on September 19, 1985 (50 FR 38066).

The EPA standards apply to spent nuclear fuel, high-level radioactive waste as defined by the Nuclear Waste Policy Act (NWPA), and TRU waste containing more than 100 nCi/g of alpha-emitting TRU isotopes. They are divided into two subparts, described below.

Subpart A, "Standards for Management and Storage," sets limits on annual doses to members of the public from management and storage operations at any disposal facility that is operated by DOE and not regulated by the NRC. The standards provide that the management and storage of waste at such facilities shall be conducted in such a manner as to provide reasonable assurance that the combined annual dose equivalent to any member of the public in the general environment from such operations shall not exceed 25 mrem to the whole body and 75 mrem to any critical organ. Because the WIPP will not be a disposal facility as defined by 40 CFR Part 191 during the Test Phase, Subpart A technically does not apply to management and storage operations at the WIPP during the Test Phase. However, as discussed below, the DOE has agreed with the State of New Mexico that the DOE will comply with the standards of Subpart A upon the initial receipt of waste at the WIPP and thereafter. The final safety analysis report (Subsection 10.2.7), which will be issued by the DOE prior to the receipt of waste, will document the DOE's ability to comply with the provisions of Subpart A. [Note: An EPA "working draft" of revisions to 40 CFR Part 191 dated June 2, 1989, proposes to modify Subpart A so that its applicability would not be limited to DOE disposal facilities but would include management and storage at other types of facilities as well. Thus, Subpart A may apply to the WIPP Test Phase under repromulgated regulations.]

Subpart B, "Standards for Disposal," establishes several sets of requirements:

- Containment Requirements: limit projected releases of radioactivity to the "accessible environment" for 10,000 years after disposal
- Assurance Requirements: (six in all) selected to provide confidence that containment requirements can be met
- Individual Protection Requirements: limit annual exposures to members of the public in the accessible environment to 25 mrem to the whole body or 75 mrem to any organ for 1,000 years after disposal

- Groundwater Protection Requirements: limit radioactive concentrations in Class I groundwaters for 1,000 years after disposal

- Guidance for Implementation: provides EPA guidance for compliance with the various numerical standards.

The assurance requirements (40 CFR 191.14) mandate, among other things, active institutional controls (e.g., boundary markers, land records entries, etc.) over disposal sites for as long a period of time as is "practicable" after disposal. However, for the purposes of assessing the performance of a geologic repository, these institutional controls may be assumed to contribute to waste isolation only during the first 100 years following disposal.

The containment requirements of 40 CFR 191.13 require that radioactive waste disposal systems be designed to provide a "reasonable expectation" that cumulative releases of radionuclides over 10,000 years will not exceed the levels specified in Appendix A, Table 1. It is not anticipated by the standards that containment requirements will be met with absolute assurance, since "there will inevitably be substantial uncertainties in projecting disposal system performance" [40 CFR 191.13(b)].

Performance assessments designed to provide a reasonable expectation that the WIPP will comply with the 40 CFR Part 191 geologic repository containment and individual protection requirements are part of the Test Phase discussed in Subsection 3.1.1.4 and Appendix O. If the performance assessments indicate that the WIPP does not have a reasonable expectation of complying with the Subpart B requirements, the DOE will consider a number of options, as discussed in Subsection 2.5.

Deciding on a challenge to the EPA standards by the Natural Resources Defense Council and others, the U.S. Court of Appeals for the First Circuit vacated and remanded Subpart B of the regulation (NRDC v. EPA, 824 F.2d 1258). Thus, legally, Subpart B portions of the radiation environmental protection standards are not now in effect.

Following the court's decision in NRDC v. EPA, the DOE and the State of New Mexico on August 4, 1987, entered into an agreement, referred to as the Second Modification to the "Agreement for Consultation and Cooperation" (Subsection 10.3.2), which provides that the DOE will:

- Comply with the standards of 40 CFR Part 191, Subpart A upon the initial receipt of waste at the WIPP and thereafter

- Provide the State by February 1, 1988, with a plan describing the steps DOE will undertake to demonstrate compliance with the assurance requirements of 40 CFR 191.14

- Prior to receiving more than 15 percent, by volume, of the WIPP's TRU waste capacity, demonstrate that the WIPP meets the applicable environmental standards for the disposal of radioactive waste established in Subpart B of

the EPA standards, including the assurance requirements under such Subpart B, in effect at that time.

In recognition of the fact that Subpart B of 40 CFR Part 191 had been vacated and remanded for reissuance, the Second Modification provided as follows:

> While the standards are on remand to the EPA for reconsideration pursuant to the July 17, 1987, opinion . . . DOE agrees to continue its performance assessment planning as though the provisions of 40 CFR 191 effective November 19, 1985, remain applicable.

The DOE will continue to guide its performance assessment efforts as though the various assurance requirements and environmental protection standards of the vacated regulations are still in effect.

[Note: In response to the NRDC v. EPA decision, the EPA has prepared a "working draft" of modifications to 40 CFR Part 191. Although the court vacated and remanded Subpart B, the EPA working draft suggests modifications to both Subpart A and Subpart B. One suggested modification previously mentioned is that the applicability of Subpart A would not be limited to DOE "disposal" facilities as is currently the case under 40 CFR 191.01(b) and 191.03(b). The working draft also contains two options for defining "disposal":

- Permanent isolation with no intent of recovery whether or not the emplaced waste is retrievable. Disposal in a mined geologic repository (e.g., WIPP) would occur when all shafts are backfilled and sealed.

- Placement in a "disposal" system except that "placements for experimental purposes that include pre-established plans for the removal of the . . . waste do not constitute disposal." (Emphasis added)

Thus, under either option of the current EPA working draft, the WIPP would not qualify as a "disposal" facility subject to the Subpart B requirements during the approximate five-year Test Phase. This is consistent with the DOE position that the WIPP is not required to demonstrate compliance with Subpart B standards prior to the Test Phase.

10.2.5 Nuclear Regulatory Commission (NRC) TRUPACT-II Certification

The 1980 FEIS, in Subsection 6.1, committed the DOE to comply with U.S. Department of Transportation (DOT) regulations and corresponding NRC regulations applicable to the WIPP. The Second Modification of August 4, 1987, to the Agreement for Consultation and Cooperation between DOE and the State of New Mexico, discussed in Subsection 10.3.2, contains the following provision:

> The transportation of radioactive waste to WIPP shall comply with the applicable regulations of the U.S. Department of Transportation and any applicable corresponding regulations of the U.S. Nuclear Regulatory Commission. All waste shipped to WIPP will be shipped in packages which the Nuclear Regulatory Commission has certified for use.

The applicable DOT regulations are contained in 49 CFR Parts 171 through 177 "Hazardous Materials Regulations." Packaging requirements for radioactive materials, including requirements for Type B packages proposed for shipments of TRU waste to the WIPP, are detailed in 49 CFR Part 173, Subpart I, which references the NRC regulations.

The NRC requirements for "Packaging and Transportation of Radioactive Materials" are contained in 10 CFR Part 71, which references the DOT regulations. Package approval standards are set forth in 10 CFR Part 71, Subpart E.

Further details on the compliance of the TRU waste shipping containers with NRC regulations are provided in Appendix L.

10.2.6 Transportation Regulations

Several federal agencies have responsibilities concerning the transport of radioactive and hazardous materials. These responsibilities can be categorized, in general, as:

- Requirements for licenses, certificates, and permits
- Requirements for packaging of nuclear materials
- Information on nuclear materials in transit
- Security and safeguards
- Routing of shipments
- Emergency response
- Financial protection
- Enforcement of regulations.

Department of Transportation (DOT). The DOT transportation regulations for hazardous and radioactive materials, promulgated under the Hazardous Materials Transportation Act (HMTA), are published in 49 CFR Parts 100-177. Regulations in 49 CFR Part 173 (and the parallel NRC regulations in 10 CFR Part 71) specify the kinds of packages to be used for the various types of radionuclides that are transported by highway, rail, air, and water. In addition to the general packaging requirements, the DOT regulations in 49 CFR Part 173, Subpart I, regulate the following:

- Type A and Type B packaging design
- Type A and Type B packaging tests
- Special packaging requirements, such as security seals, or authorized packaging for fissile materials, pyrophoric materials, and oxidizing materials

- Specific marking, labeling, and placarding for radioactive materials
- Identification of radioactive materials on the shipping papers
- Driver qualifications, loading, unloading, and vehicle maintenance
- NRC approved packaging.

The HMTA allows States to regulate the transport of hazardous/nuclear materials, as long as such regulations are consistent with the HMTA or DOT regulations. In cases of conflict or inconsistency, the doctrine of Federal "preemption" generally applies.

The DOT regulations in 49 CFR 177.825 provide a routing rule for highway route controlled quantities of radioactive materials (WIPP shipments fall into this category). This routing rule permits States and Indian Tribes to designate routes in accordance with DOT guidelines or an equivalent routing analysis. Interstate highways must be used in the absence of a State- or Tribal-designated route, unless a deviation is necessary.

Currently, there are no routing requirements under the DOT for shipment of radioactive material by rail. The general DOT regulations for packaging, labeling, and placarding of radioactive materials apply to rail shipment. Special handling requirements and rules for segregating radioactive materials from other waste when shipping by rail are contained in 49 CFR Part 174.

Nuclear Regulatory Commission (NRC). Under a procedural agreement between the DOE and the NRC, the NRC also has the responsibility to certify the safety of the packaging to be used specifically for transporting TRU waste to the WIPP (i.e., the TRUPACT-II and the forthcoming remote-handled [RH] TRU waste cask). The TRUPACT-II was certified for shipment of contact-handled (CH) TRU waste by the NRC on August 30, 1989.

NRC regulations addressing the packaging and transportation of radioactive materials are found in 10 CFR Part 71. The regulations pertain to:

- NRC approved packages (licenses and standards)
- Type A and Type B packages
- Package tests
- Operating controls and procedures.

Environmental Protection Agency (EPA). The EPA oversees the transport of radioactive mixed waste under RCRA. The July 3, 1986 Federal Register publication (51 FR 24504) described in Subsection 10.2.1 set out EPA's determination that waste containing both hazardous and radioactive contaminants is subject to regulation under RCRA.

The EPA has adopted certain DOT regulations governing the transportation of hazardous materials and has incorporated them into RCRA regulations for generators and transporters in 40 CFR Parts 262 and 263. These regulations are primarily concerned with labeling, marking, placarding, using proper containers, and reporting discharges.

RCRA regulations in 40 CFR 262.20 require hazardous waste generators to ship their waste to a "designated facility" which is permitted under RCRA to handle the waste. The WIPP will qualify as a permitted facility under interim status before any waste is shipped from any generator facility (Subsection 10.2.1).

10.2.7 Final Safety Analysis Report

The FSAR is being prepared to satisfy the requirements of DOE Order 5481.1B Safety Analysis and Review System, and the commitments made in the Working Agreement for Consultation and Cooperation between the State of New Mexico and the DOE. The purpose of the FSAR is to document that a systematic analysis of the potential hazards associated with operating the WIPP has been performed, that potential consequences have been analyzed, and that reasonable measures have been taken to control or mitigate the hazards.

The scope of the FSAR is to address hazards for the 25-year design life of the WIPP, acknowledging that the decision to operate the plant for 25 years has not been made and will not be made until the DOE can successfully demonstrate compliance with applicable regulations. The FSAR considers operations at waste throughput rates equivalent to the design basis with the general belief that lesser throughput rates and shorter operating periods are bounded by the design conditions. In this regard, the FSAR bounds the Test Phase during which time various tests, experiments, and demonstrations would occur which have been designed to support a decision regarding the Disposal Phase.

SARs are controlled documents that are updated periodically. The designation "Final" is given to indicate that a Safety Analysis Report is for a facility that is ready to begin operating versus a "Preliminary" SAR which generally refers to a facility in the design or construction stage. As indicated above, FSARs must be amended to reflect significant changes in operations or in the factors that affect operation; the FSAR will be reviewed at least every three years.

A summary of the Test Phase experiments is included in Appendix O of this final SEIS. The plan for the Test Phase is referenced in Appendix O.

10.3 OVERSIGHT ORGANIZATIONS

Several State of New Mexico and Federal agencies and groups currently provide oversight regarding various aspects of the WIPP project. For some agencies, such as the EPA, this oversight role has increased since the FEIS was published due to changes in regulatory requirements since 1980. For others, such as the recently appointed "Blue Ribbon Review Panel" on the WIPP, the oversight entity and its

responsibilities were created after publication of the draft SEIS. Because the pattern and breadth of oversight for the WIPP project has changed since 1980, this subsection has been prepared to provide an overview of current and expected oversight of the WIPP project.

10.3.1 Environmental Protection Agency

As discussed in Subsections 10.2.1, 10.2.2, and 10.2.4, the EPA's oversight role is that of a regulating agency. Under the RCRA, the EPA (or the State of New Mexico) will issue the DOE a permit to operate the WIPP as a hazardous waste management facility. Under the Clean Air Act, the EPA will evaluate the DOE's notice of facility start-up and compliance with the NESHAP. The EPA has established radiation protection standards for the management and storage of TRU waste at disposal sites and is undertaking a rule making to establish standards for the disposal of TRU waste.

10.3.2 State of New Mexico

The Department of Energy National Security and Military Applications of Nuclear Energy Authorization Act of 1980 (PL 96-164), which authorized the WIPP project (Subsection 1.1), provides as follows in Section 213(b):

1) In carrying out such project, the Secretary shall consult and cooperate with the appropriate officials of the State of New Mexico, with respect to the public health and safety concerns of such state in regard to such project and shall, consistent with the purposes of subsection (a), give consideration to such concerns and cooperate with such officials in resolving such concerns. The consultation and cooperation required by this paragraph shall be carried out as provided in paragraph 2.

2) The Secretary shall seek to enter into a written agreement with the appropriate officials of the State of New Mexico, as provided by the laws of the State of New Mexico, not later than September 30, 1980, setting forth the procedures under which the consultation and cooperation required by paragraph 1 shall be carried out. Such procedures shall include as a minimum:

   a) the right of the State of New Mexico to comment on, and make recommendations with regard to, the public health and safety aspects of such project before the occurrence of certain key events identified in the agreement

   b) procedures, including specific time frames, for the Secretary to receive, consider, resolve, and act upon comments and recommendations made by the State of New Mexico

   c) procedures for the Secretary and the appropriate officials of the State of New Mexico to periodically review, amend, or modify the agreement.

In 1981, the State of New Mexico brought suit in the United States District Court for the District of New Mexico (State of New Mexico v. U.S. Department of Energy, Civil Action No. 81-0363 JB) to address four State concerns:

1) That no decision on WIPP construction be made until the DOE shared with the State the results of the SPDV

2) That the State be assigned "final resolution" of all off-site State health and safety concerns prior to WIPP construction

3) That the State and the DOE enter into a "binding and enforceable consultation and cooperation agreement"

4) That the FLPMA be complied with for any withdrawal of lands from the public domain for the WIPP.

Subsequently, the District Court ordered a "stay" (postponement) of the suit in recognition of the fact that the State and the DOE had entered into a "Stipulated Agreement Resolving Certain State Off-site Concerns Over WIPP."

The Stipulated Agreement has 14 provisions, the principal one being that the DOE and the State of New Mexico execute a "consultation and cooperation agreement" in order to provide "timely exchange of information" about the WIPP. The Consultation and Cooperation Agreement also provides for conflict resolution on matters "relating to the public health, safety or welfare of the citizens of the State."

A "Working Agreement" for the Consultation and Cooperation Agreement was appended to the Consultation and Cooperation Agreement as Appendix A. The "Working Agreement" has 11 major articles. Among other things, it provides for the DOE to give prior written notice to the State before the occurrence of 17 "key events" or "milestones" during the life of the project, up to and including decontamination and decommissioning.

The Stipulated Agreement was supplemented on December 27, 1982. This Supplemental Stipulated Agreement, the filing of which completed the lawsuit settlement process, addressed five major areas:

- State liability
- Emergency response preparedness
- Transportation monitoring of WIPP waste
- WIPP environmental operations monitoring by the State of New Mexico
- Upgrading of State highways.

These agreements between the State and the DOE are available to the public and have been placed in certain libraries and reading rooms around the State (see Appendix K).

The Consultation and Cooperation Agreement and the "Working Agreement" for the Consultation and Cooperation Agreement have been modified several times by mutual agreement as follows:

- Working Agreement for Consultation and Cooperation Agreement, Revision 1 - March 22, 1983.

- First Modification to the Agreement for Consultation and Cooperation--November 27, 1984. This modification addressed six issues: 1) specific mission of the WIPP, 2) demonstrating retrievability of WIPP waste, 3) post-closure control, 4) completion of additional testing, 5) compliance with applicable Federal regulatory standards, and 6) encouraging the hiring of New Mexico residents at the WIPP site.

- Second Modification to the Agreement for Consultation and Cooperation--August 4, 1987. This modification addressed surface and subsurface mining, salt disposal, and compliance with applicable EPA, DOT, and NRC regulations.

- Modification to the Working Agreement of the Consultation and Cooperation Agreement--March 22, 1988. This modification addressed on-going field investigations, monitoring and testing, and established "target dates."

The institutional bodies specifically charged with implementing these various agreements and modifications for the State are the New Mexico Radioactive Waste Consultation Task Force and the Environmental Evaluation Group. In addition, the DOE interfaces regularly with the New Mexico Environmental Improvement Division and with the New Mexico Legislature's Radioactive and Hazardous Waste Committee, as those bodies carry out oversight activities on behalf of the State.

10.3.2.1 Environmental Evaluation Group. The Environmental Evaluation Group (EEG) was established in 1978 with funds provided by the DOE to the State of New Mexico. Public Law 100-456, the National Defense Authorization Act, Fiscal Year 1989, provides in Section 1433 for the DOE to contract with the New Mexico Institute of Mining and Technology for the conduct of "independent reviews and evaluations" pertaining to the WIPP. The legislation further directs the Institute to perform these reviews through the EEG. The EEG performs independent technical analyses of the suitability of the WIPP site; the design of the repository, its planned operation, and its long-term integrity; suitability and safety of the transportation systems; suitability of the Waste Acceptance Criteria (WAC) and the generator facilities' compliance with them; and related subjects. These analyses include assessments of reports issued by the DOE and its contractors, other federal agencies, and organizations as they relate to the potential health, safety, and environmental impacts from WIPP. The EEG also performs environmental monitoring for background radioactivity in air, water, and soil, both on-site and in surrounding communities (see Subsection 2.9.5). To date, the EEG has published 42 independent reports of these aspects of the WIPP.

10.3.2.2 New Mexico Environmental Improvement Division. The New Mexico Environmental Improvement Division (EID) has regulatory oversight over the WIPP in the

areas of water quality, air quality, and solid and hazardous waste management and disposal. The EID is responsible for ensuring the WIPP's compliance with State environmental laws, such as the New Mexico Hazardous Waste Act, the New Mexico Water Quality Act, and the New Mexico Air Quality Control Act. State permits for various activities are issued by the EID.

10.3.2.3 New Mexico Radioactive and Hazardous Waste Committee. The New Mexico Radioactive and Hazardous Waste Committee was created by the Radioactive Waste Consultation Act passed by the New Mexico Legislature in 1979. The Committee is composed of eight members, four from the State House of Representatives and four from the State Senate. The Committee, which meets monthly, examines areas relevant to the issue of radioactive and hazardous waste disposal in the State of New Mexico. At the request of the Committee, the DOE appears before it several times a year to apprise the Committee of project progress and answer any questions or concerns that the Committee may have about the WIPP, including environmental, safety, and health issues. In this oversight capacity, the Committee reports to the full legislature and submits for its consideration any recommended legislation that the Committee deems necessary to ensure the safe operation of the WIPP.

10.3.2.4 New Mexico Radioactive Waste Consultation Task Force. The New Mexico Radioactive Consultation Task Force was also created by the Radioactive Waste Consultation Act passed by the New Mexico Legislature in 1979. The Task Force consists of the Secretaries of Energy, Minerals, and Natural Resources; Highway and Transportation; Health and Environment; and the Chief Highway Administrator (or their designees). The Task Force serves as the official entity in New Mexico for negotiation with the Federal government in areas relating to siting, licensing, and operation of new Federal disposal facilities for radioactive waste. Although not specifically charged with environmental oversight of the WIPP, the Task Force negotiates with the DOE on matters that impact health and safety issues in New Mexico. For example, the Task Force has been involved in negotiating agreements with the DOE to provide funding for emergency response supplies and training, as well as highway and bypass road construction, as they pertain to WIPP operations.

10.3.3 National Academy of Sciences

The WIPP Panel of the Board on Radioactive Waste Management of the National Academy of Sciences (NAS) was formed to review the scientific and technical aspects of the WIPP project. The Panel consists of scientists and technical experts from various fields such as geochemistry, geohydrology, statistical modeling, health physics, public safety, facility engineering, and systems engineering. The Panel reviews the data and documents associated with the development and implementation of the WIPP. Originally involved in site selection and site characterization, the NAS WIPP Panel has continued its oversight role by reviewing WIPP activities pertaining to repository performance assessment, preoperational test activities, industrial and radiological safety, and other geotechnical and hydrogeological aspects of WIPP operations. The NAS WIPP Panel's oversight has included review of the proposed Test Plan. The WIPP Panel reports to the Board, which in turn makes recommendations to the DOE regarding the WIPP. The Academy also provides feedback to Congress to aid it in its oversight of the WIPP.

10.3.4 Advisory Committee on Nuclear Facility Safety

The Advisory Committee on Nuclear Facility Safety was formed under the provisions of the Federal Advisory Committee Act (Public Law 92-463). The Committee was established to provide the Secretary of Energy with advice and recommendations concerning the safety of the DOE's production and utilization facilities, as defined in Section II of the Atomic Energy Act of 1954, as amended. The Committee has inspected the WIPP facility and observed mock waste emplacement demonstrations. They have reviewed technical information on the FSAR, SEIS, and Test Plan. The Committee has also served as a focal point for receiving feedback from other oversight groups and the public. The Committee reports directly to the Secretary of Energy.

10.3.5 "Blue Ribbon Review Panel"

To further the goal of independent, objective oversight of the WIPP project, a "Blue Ribbon Review Panel" has been formed, consisting of members selected by the Secretary of Energy and by the Governors of Idaho, Colorado, and New Mexico. The Panel members report their findings to the Secretary of Energy. The Panel is reviewing the current plans for demonstrating the WIPP's technical and operational adequacy. The Panel's review includes 1) the relative benefits of the Performance Assessment and Operations Demonstration; 2) the examination of the concept and timing of the Operations Demonstration; and 3) the recertification plan for the Rocky Flats Plant TRU waste. The Panel members submitted reports to the Secretary of Energy on their initial findings in October 1989. The Panel will continue to review the adequacy of the WIPP to accept and dispose of defense TRU waste.

10.3.6 Mine Safety and Health Administration (MSHA)

Under the Federal Mine Safety and Health Act of 1977, the U.S. Department of Labor is responsible for developing and enforcing regulations and standards to protect mine workers. Under a Memorandum of Understanding (MOU) between the DOE and the Department of Labor, effective July 9, 1987, the Mine Safety and Health Administration (MSHA) conducts periodic health and safety compliance assistance inspections of WIPP mining operations. The MSHA does not have regulatory jurisdiction over the WIPP, rather it advises the DOE of appropriate actions to be taken to assure the timely correction of any deficiencies noted during these inspections. MSHA also may participate in investigations in the event of an accident or fatality at the WIPP site.

REFERENCES FOR SECTION 10

Bertram-Howery, S. G., and R. L. Hunter, 1989. Plans for Evaluation of the Waste Isolation Pilot Plant's Compliance with EPA Standards for Radioactive Waste Management and Disposal, SAND88-2871, Sandia National Laboratories, Albuquerque, New Mexico.

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EPA (Environmental Protection Agency), 1988. "No Migration" Variances to the Hazardous Waste Land Disposal Prohibitions: A Guidance Manual for Petitioners, draft, October 1988, Washington, D.C.

Foster, B., 1984. Transportation of Spent Fuel, High-Level Wastes, and Transuranic Wastes, SAND84-7113, TTC-0475, Sandia National Laboratories, Albuquerque, New Mexico.

GLOSSARY

absorbed dose	The energy imparted to matter by ionizing radiation per unit mass of irradiated material at the place of interest. The unit of absorbed dose is the rad. (See rad.)
actinide	An element in the series beginning with element 90 and continuing through element 103. All the transuranic nuclides considered in this document are actinides.
activity	The number of nuclear transformations occurring in a given quantity of material per unit time (See curie, radioactivity.)
acute toxicity	A disease or disorder with rapid onset, of short duration and pronounced syndromes. This results from the harmful effect(s) of a poisonous substance on the body by physical contact, inhalation, or ingestion.
AIRDOS-EPA	A computer code endorsed by the Environmental Protection Agency for predicting radiological doses to members of the public due to airborne releases of radioactive material. Includes inhalation, external exposure to direct radiation, and food ingestion pathways.
alpha particle	A charged particle emitted from the nucleus of an atom having a mass and charge equal in magnitude of a helium nucleus; i.e., two protons and two neutrons.
anhydrite	A mineral consisting of anhydrous calcium sulfate: $CaSO_4$. It is gypsum without its water of hydration and is denser, harder, and less soluble than gypsum.
anticline	A fold of rocks whose core contains the stratigraphically older rocks; it is convex upward.
aquiclude	The saturated but poorly permeable underground formation that impedes groundwater movement and does not yield water freely to a well or spring.
aquifer	A body of rock that contains enough saturated permeable material to transmit groundwater and to yield significant quantities of groundwater to wells and springs. The opposite of an aquiclude.

arcuate	Curved or arc-like fractures in a geologic medium. These fractures can be convex or concave depending upon the stress field at the location of the fractures.
argillaceous rocks	Rocks containing appreciable amounts of clay.
atom	Smallest unit of an element which is capable of entering into a chemical reaction.
average life	The average of the individual lives of all the atoms of a particular radioactive substance. It is 1.443 times the radioactive half-life.
backfill	Salt, or a mixture of salt and other materials, used to reduce void volumes in storage panels and drifts.
background radiation	Radiation arising from radioactive material other than the one directly under consideration. Background radiation due to cosmic rays and natural radioactivity is always present. There may also be background radiation due to the presence of radioactive substances in other parts of a building, in the building material itself, etc.
basin	An extensive depressed area having no surface outlet into which the adjacent land drains.
bedded salt	Consolidated layered salt separated from other layers by distinguishable planes of separation.
Bell Canyon Formation	A sequence of rock strata that forms the topmost unit of the Delaware Mountain Group.
berm	A narrow ledge or shelf, as along a slope.
beta particle	Charged particle emitted from the nucleus of an atom, with a mass and charge equal in magnitude to that of the electron.
bin-scale tests	Sealed bins where TRU wastes and other materials are stored in order to determine chemical and physical interactions.
boiling point	The temperature at which the transition from the liquid to the gaseous phase occurs in a pure substance at fixed pressure.
breccia	A clastic sedimentary rock composed of angular rock fragments greater than 2 mm in diameter.

caliche caprock	A desert soil formed by the near-surface crystallization of calcite and/or other soluble minerals by upward-moving solutions.
canister	As used in this document, a container, usually cylindrical, for remotely handled waste, spent fuel, or high-level waste. The waste will remain in this canister during and after burial. A canister affords physical containment but not shielding; shielding is provided during shipment by a shipping cask.
carcinogen	A substance that causes or induces cancer.
CAS number	Chemical Abstract System numbering system for chemical identification and classification as proposed by the American Chemical Society.
cask	A massive shipping container providing shielding for highly radioactive materials and holding one canister.
Castile Formation	A formation of evaporite rocks (interbedded halite and anhydrite) of Permian age that immediately underlies the Salado Formation.
chronic toxicity	A disease or disorder which is long continued, or is of long duration. This results from the harmful effect(s) of a poisonous substance on the body by physical contact, inhalation, or ingestion.
clastic	Referring to a rock or sediment composed primarily of broken fragments of pre-existing rocks or organisms.
cloudshine	The exposure from cloudshine is the direct external dose from the passing cloud of dispersed material.
committed dose equivalent	The dose equivalent to organs or other tissues that will be received following an intake of radioactive material during the 50-year period following that intake.
committed effective dose equivalent	The weighted sum of committed dose equivalents to dose organs, using weighting factors based on the susceptibility of each organ to certain health effects.
conservative	When used with predictions or estimates, leaning on the side of pessimism. A conservative estimate is one in which the uncertain inputs are used in the way that maximizes the impact.

contact-handled waste	Waste that does not require shielding other than that provided by its container in order to protect those handling it.
contamination	Deposition of radioactive material in any place where it is not desired, particularly where its presence may be harmful.
control zone	At the WIPP, one of several areas of land whose use is governed by controls and restrictions.
creep	1) The slow, imperceptible motion of rock material downslope by gravitational forces. 2) The continuous, usually slow deformation of rock resulting from constant stress acting over a long period of time.
creep closure	Closure of underground openings, especially openings in salt, by plastic flow of the surrounding rock under lithostatic pressure.
criticality	The state of a mass of fissionable material when it is sustaining a chain reaction.
Culebra Dolomite	The lower of two layers of dolomite within the Rustler Formation that are locally water bearing.
curie	The special unit of activity. One curie equals 3.700×10^{10} nuclear transformations per second. Abbreviated Ci. Several fractions of the curie are in common usage. microcurie: One-millionth of a curie (3.7×10^{4} disintegrations per second). Abbreviated μCi. millicurie: One-thousandth of a curie (3.7×10^{7} disintegrations per second). Abbreviated mCi. picocurie: One-millionth of a microcurie (3.7×10^{-2} disintegrations per second or 2.22 disintegrations per minute). Abbreviated pCi; replaces the term $\mu\mu$c.
darcy	A unit of permeability equal to 10^{-12} m^2.
Darcy's Law	A means of describing flow through porous media.
daughter	Synonym for decay product.
decay (radioactive)	Process in which a nucleus emits radiation and undergoes spontaneous transformation into one or more different nuclei.

decay heat	Thermal energy (heat) generated during the radioactive decay of isotopes.
decontamination	The removal of unwanted material (especially radioactive material) from the surface or from within another material.
decommissioning	The process of removing a facility from operation. It is then mothballed, entombed, decontaminated, and dismantled or converted to another use.
defense program waste	Nuclear waste deriving from the manufacture of nuclear weapons and the operation of naval reactors. Associated activities such as the research in the weapons laboratories also produce defense waste.
degradation	A process of transition. To decompose (a compound) by stages.
Delaware Basin	An area in southeastern New Mexico and adjacent parts of Texas where a sea deposited large thicknesses of evaporites some 200 million years ago. It is partially surrounded by the Capitan Reef.
diffusion	The gradual mixing of the molecules of two or more substances, as a result of random thermal motion.
diffusion, atmospheric	Movement of a contaminant due to the cumulative effect of the random motions of the air. Equivalent to eddy diffusion.
Disposal Phase	The approximately 20-year period by which DOE proposes to permanently emplace TRU wastes in the WIPP.
disturbed rock zone (DRZ)	The DRZ is a volume of rock adjacent to an underground excavation in which mechanical properties (e.g., elastic modulus) and hydraulic properties (e.g., permeability and degree of saturation) have been changed due to mining of that excavation.
dolomite	A sedimentary rock consisting primarily of the mineral dolomite ($CaMg(CO_3)_2$). It is commonly found in limestone.
dome	A roughly symmetrical upfold, the beds dipping in all directions, more or less equally from a point.
dose	A general form denoting the quantity of radiation or energy absorbed. For special purposes it must be

	appropriately qualified. If unqualified, it refers to absorbed dose. (The unit of absorbed dose is the rad.)
dose commitment	A less formal expression meaning dose equivalent commitment.
dose conversion factor	A numerical factor used in converting radionuclide uptake (curies) in the body to the resultant radiation dose or dose commitment (rem or man-rem).
dose equivalent	A quantity used in radiation protection for expressing the effects of all radiations on a common scale with respect to the relative biological effect. It is defined as the product of the absorbed dose in rads and certain modifying factors. (The unit of dose equivalent is the rem.)
drift	A horizontal mine passageway.
dual porosity	Having fracture porosity as well as interconnected pores.
dyne	The unit of force which, when acting upon a mass of one gram, will produce an acceleration of one centimeter per second per second.
eolian	Applied to deposits arranged by the wind, as the sands and other loose materials along shores, etc.
equilibrium	The state of a reaction in which its forward and reverse reactions occur at equal rates so that the concentrations of the reactants do not change with time.
epeirogenic movement	The broad movements of uplift and subsidence which affect the whole or large portions of continental areas.
erg	Unit of work done by a force of one dyne acting through a distance of one cm. Unit of energy which can exert a force of one dyne through a distance of one cm; cgs units: dyne-cm or gm-cm^2/sec^2.
evaporites	Sedimentary rocks composed primarily of minerals produced from a saline solution that became concentrated by evaporation of the solvent such as rock salt, sylvite, langbeinite, and anhydrite.
exposure	A measure of the ionization produced in air by x or gamma radiation. It is the sum of the electrical charges on all ions of one sign produced in air when all electrons liberated by photons in a volume element of air are

	completely stopped in air, divided by the mass of the air in the volume element. The special unit of exposure is the roentgen.
fault	A fracture or fracture zone along which there has been displacement of the sides relative to one another. normal fault: A fault at which the hanging wall has been depressed, relative to the footwall. thrust fault: A reverse fault that is characterized by a low angle of inclination with reference to a horizontal plate.
Federal Land Policy and Management Act (FLPMA)	This 1976 Act governs DOI activities, including administrative withdrawal of BLM public lands. (Section 204)
Final Safety Analysis	This document, prepared in compliance with DOE Order 5481.1B, is the completed formal evaluation of WIPP facilities and operations to systematically identify the hazards of operations, to describe and analyze the adequacy of the measures taken to eliminate, control, or mitigate identified hazards, and to analyze and evaluate potential accidents and their associated risks. (Currently being finalized.)
Final Environmental Statement Impact (FEIS)	This document was prepared by DOE in 1980 in accordance with the National Environmental Policy Act of 1969. This report identifies and analyzes in detail the environmental impacts of the proposed action to place defense-generated transuranic wastes at the WIPP and the feasible alternatives.
fissile	Of a nuclide, capable of undergoing fission by interaction with slow neutrons.
fission (nuclear)	A nuclear transformation characterized by the splitting of a nucleus into a least two other nuclei and the release of a relatively large amount of energy.
fission product	An element or compound resulting from fission.
fluid inclusion	A small opening in a rock mass (salt) containing brine; also the brine included in such an opening. Some gas is often also present.
fluvial	Of, or pertaining to, rivers; produced by river action.

forb	A non-woody plant that is not grass or grass-like.
40 CFR Part 191	EPA standard for managing and disposing of spent nuclear fuel and high-level and transuranic wastes. Subpart A deals with managing and storage of wastes while Subpart B covers long-term isolation and disposal.
fraction	A small part of the total. The particulate fraction is that part of the waste in a particulate form.
fugitive dust	Soil particles entrained in air due to construction equipment, vehicles, or wind erosion.
gamma ray	Short wavelength electromagnetic radiation emitted from the nucleus with typical energies ranging from 10 keV to 9 MeV.
gas getter	Materials which have an ability to remove gases from the atmosphere by chemical means.
geosyncline	Large, generally linear trough that subsided deeply throughout a long period of time during which a thick succession of stratified sediments and possibly extrusive volcanic rocks commonly accumulated.
glove box	A sealed box in which workers, remaining outside and using gloves attached to and passing through openings in the box, can safely handle and work with radioactive materials.
groundshine	The exposure from groundshine is the direct external dose from material that has deposited on the ground after being dispersed from an accident site.
groundwater	All subsurface water, especially that which comprises the zone of saturation beneath the water table.
grout plugs	Barriers in boreholes or excavated areas consisting of grout material designed to impede liquid movement.
half-life	Time required for a radioactive substance to lose 50 percent of its activity by decay. Half-life is a unit of measure used to project the length of time that these materials remain radioactive. Each radionuclide has a unique half-life; that is, half of a particular nuclide will decay in a specified amount of time; then half of the remaining portion will decay in the same amount of time, and so on, until the material is spent.

	Half-life can also refer to the length of time that a chemical/radionuclide/biological agent remains in the body. Each material has biologically unique half-lives, depending on the substance, the organ of concern, and its route of elimination.
halite	The mineral rock salt: NaCl.
hazard index	The hazard index (HI) for a given chemical may be defined as the ratio between the daily intake of that chemical and an acceptable reference level.
hazardous waste	Nonradioactive chemical toxins or otherwise dangerous materials such as sodium, heavy metals, beryllium, and some organics.
head	When used alone, it is understood to mean static head. The static head is the height above a standard datum of the surface of a column of water (or other liquid) that can be supported by the static pressure at a given point.
headspace gases	The gases in the head space of a container that are generated from biological, chemical, and radiolytic processes occurring in the waste. The head space of a container is the space between the container lid and the waste inside the container.
health physics	A science and profession devoted to the protection of man and his environment from unnecessary radiation exposure.
HEPA filter	(High Efficiency Particulate Air.) Material that captures entrained particles from an air stream, usually with efficiencies in the 99.95% and above range for particle sizes of 0.3 micron. Filter material is usually a paper or fiber sheet that is pleated to increase surface area.
hepatotoxin	An agent capable of damaging the liver.
high-level waste	Radioactive waste resulting from the reprocessing of spent nuclear fuel. Discarded, unreprocessed spent fuel is also high-level waste. It is characterized by intense, penetrating radiation and by high heat-generation rates. Even in protective canisters, high-level waste must be handled remotely.
horizon	In this document, an underground level. The waste-emplacement horizon in the WIPP is the level about

	2,150 feet deep at which openings would be mined for waste disposal.
hot cell	A heavily shielded enclosure for handling and processing (by remote means or automatically) or storing highly radioactive materials.
hydraulic conductivity	A quantity defined in the study of groundwater hydraulics that describes the rate at which water flows through an aquifer. It is measured in feet per day or equivalent units. It is equal to the hydraulic transmissivity divided by the thickness of the aquifer.
hydraulic transmissivity	A quantity defined in the study of groundwater hydraulics that describes the rate at which water may be transmitted through an aquifer. It is measured in ft^2/day or equivalent units.
IDLH	Immediately Dangerous to Life or Health represents a maximum airborne concentration from which one could escape within 30 minutes without any escape-impairing symptoms or any irreversible health effects.
igneous	A rock or mineral that formed from molten material.
in situ	In the natural or original position. The phrase is used in this document to distinguish in-place experiments, rock properties, and so on, from those in the lab.
integrated release	As defined by the EPA in 40 CFR Part 191, the integrated release is the total cumulative release over the full width of the contaminant plume for a period of 10,000 years.
isotopes	Atoms having the same number of protons in their nuclei, but differing in the number of neutrons. Almost identical chemical properties exist between isotopes of a particular element.
IUPAC name	Nomenclature for chemical substances proposed by the International Union of Pure and Applied Chemists.
karst	An erosional topography characterized by sinkholes, caves, and disappearing streams formed by groundwater in limestone, dolomite, and evaporite bedrock.
kelvin	A unit of temperature equal to what used to be called the degree Centigrade; abbreviated K.

langbeinite	A mineral used by the fertilizer industry as a source of potassium sulfate.
LD_{50} (LC_{50})	The dose (or concentration in the case of tests with aquatic organisms) of a substance which is lethal to 50% of the test organisms.
Linear Energy Transfer	The rate at which energy is deposited in a medium as radiation passes through the medium. For example, alpha particles are low penetrating and high LET radiation because they give up their energy quickly to matter while X-rays are high penetrating and low LET radiation.
lithic	Pertaining to or consisting of stone.
lithostatic pressure	The vertical pressure at a point in the Earth's crust, equal to the pressure exerted by the weight of the overlying rock and/or soil.
Los Medanos	The geographic name for the area surrounding the WIPP site in southeastern New Mexico. In Spanish it means "dune country."
low-level waste	Radioactive waste not classified as high-level waste, TRU waste, spent nuclear fuel, or byproduct material (as defined by DOE Order 5820.2).
man-rem	A unit of population dose; used interchangeably with person-rem.
material-at-risk	The fraction of each radionuclide or hazardous chemical component of the total inventory available for release in a given scenario.
maximally exposed individual	A hypothetical person who is exposed to a release of radioactivity in such a way that he receives the maximum possible individual dose or dose commitments. For instance, if the release is a puff of contaminated air, the maximally exposed person is at the point of largest ground-level concentration, and remains there during the total time of cloud passage. The use of this term is not meant to imply that there really is such a person, but only that thought is being given to the maximum exposure a person could receive.
melting point	The temperature at which a pure solid normally changes to the corresponding liquid form of the substance.

metamorphism	Process by which consolidated rocks are altered in composition, texture, or internal structure by conditions and forces not resulting simply from burial and the weight of subsequently accumulated overburden.
micro-	A prefix meaning one millionth (1/1,000,000 or 10^{-6}).
milli-	A prefix meaning one thousandth (1/1,000 or 10^{-3}).
molecular weight	The weight of a molecule of a chemical expressed in atomic mass units.
Monte Carlo method	A method permitting the solution by means of a computer of problems of physics, such as those of neutron transport, by determining the history of a large number of elementary events by the application of the mathematical theory of random variables.
mutagen	A physical or chemical agent which raises the frequency of mutation in a population (alteration, change, or rearrangement of the genetic material or DNA of an organism), above the spontaneous rate.
nano-	A prefix meaning one billionth (1/1,000,000,000 or 10^{-9}).
narcosis	State of profound stupor, unconsciousness, or arrested activity.
Nash Draw	A shallow 5-mile-wide valley open to the southwest, *located to the west of the WIPP facility.
National Environmental Policy Act (NEPA)	This 1969 Act was designed to promote inclusion of environmental concerns in Federal decision-making.
nephrotoxin	An agent capable of damaging the functional units of the kidneys (ephrons and associated glomeruli).
nuclide	A species of atom characterized by the number of protons (Z), number of neutrons (N), and energy state.
Octanol/Water Partition Coefficient	An indicator for a compound's affinity for the solvent or aqueous phase. Compounds with high octanol/water partition coefficients tend to have higher affinity for the solvent phase and the potential to accumulate in the fatty tissue of an organism.
order of magnitude	A factor of ten. When a measurement is made with a result such as 3×10^{7}, the exponent of 10 (here 7) is the order of magnitude of that measurement. To say that this

order of magnitude	A factor of ten. When a measurement is made with a result such as 3×10^7, the exponent of 10 (here 7) is the order of magnitude of that measurement. To say that this result is known to within an order of magnitude is to say that the true value lies between (in this example) 3×10^6 and 3×10^8.
overpack	A container put around another container. In the WIPP, overpacks would be used on damaged or otherwise contaminated drums, boxes, and canisters that it would not be practical to decontaminate.
package	In the NRC regulations governing the transportation of radioactive materials (10 CFR Part 71), the term "package" is used to mean the shipping container or cask.
packaging	In the NRC regulations governing the transportation of radioactive materials (10 CFR Part 71), the term "packaging" is used to mean the shipping container together with its radioactive contents.
particulates	Fine liquid or solid particles such as dust, smoke, or fumes found in the air or emissions.
peneplain	A nearly flat land surface representing an advanced stage of erosion.
permeability	A property of a mass of soil or rock defined in the study of groundwater hydraulics as the rate at which water can flow through that mass. It is a measurement of the rock's capacity to transmit fluids. It is a function of the medium but not of the fluid. Units are darcy or m^2 or equivalent (1 darcy $\approx 10^{-8} cm^2$).
person-rem	A unit of population dose; used interchangeably with man-rem.
pico-	A prefix meaning one trillionth (1/1,000,000,000,000 or 10^{-12}).
plutonium equivalent curie (PE-Ci)	A radioactive hazard index factor which relates the radiotoxicity of TRU radionuclides to that of plutonium-239 (see SEIS Appendix F).
pluvial	Due to the action of rain.
polyhalite	An evaporite mineral: $K_2MgCa_2(SO_4)_4 \cdot 2H_2O$. It is a hard, poorly soluble mineral with no economic value.

porosity	The porosity of a rock or soil is its property of containing interstices or voids and may be expressed quantitatively as the ratio of the volume of its interstices to its total volume.
potash	A potassium compound, especially as used in agriculture or industry.
potentiometric surface	The surface of the hydraulic potentials of an aquifer. It is usually represented in figures as a contour map, in which each point which tells how high the water would rise in a well tapping that aquifer at that point.
preoperational appraisal	An appraisal whose purpose is to determine whether procedures and hardware are sufficient to allow a facility to become operational. The term "operational readiness review" is sometimes used for "preoperational appraisal."
pyrophoric	Spontaneously igniting in air; producing sparks by friction.
rad	The unit of absorbed dose equal to 100 ergs/g (0.01 J/kg) in any medium. (See absorbed dose.)
radioactive mixed waste	Radioactive mixed waste is defined as any radioactive waste that is commingled with RCRA-regulated hazardous wastes as defined in 40 CFR Part 261, Subparts C and D.
radiation	Particles or energy emitted from an unstable atom as a result of radioactive decay.
radioactivity	The property of certain nuclides of spontaneously emitting particles or energy or of undergoing spontaneous fission.
radiography	The making of shadow images on photographic emulsion by the action of ionizing radiation. The image is the result of the differential attenuation of the radiation in its passage through the object being radiographed.
radiolysis	Chemical decomposition by the action of radiation.
radionuclide	An unstable nuclide of an element that decays or disintegrates spontaneously, emitting radiation.
radionuclide inventory (nuclide inventory)	A list of the types and quantities of radionuclides in a container or source. Amounts are usually expressed in activity units: curies or curies per unit volume.

Record of Decision (ROD)	The decision document published in the Federal Register by which a Federal department or agency decides on an alternative presented and evaluated through the EIS process.
Reference Dose (RfD)	The RfD is an estimate, with uncertainty spanning perhaps an order of magnitude, of the daily exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a portion of the lifetime (subchronic RfD), or during a lifetime (chronic RfD).
refractive index	The ratio of the phase velocity of light in a vacuum to that in a specified medium; light is refracted owing to the interactions of light radiation between the electric vector and the bound electrons of the medium.
rem	A special unit for dose equivalent. It is numerically equal to the absorbed dose in rads multiplied by certain modifying factors.
remote-handled waste	Waste that requires shielding in addition to that provided by its container in order to protect those handling it and other people nearby.
repository	A facility for the storage or disposal of radioactive waste.
Resource Conservation and Recovery Act (RCRA)	This Act was designed to provide "cradle to grave" control of hazardous chemical wastes.
retrievable storage	Storage of radioactive waste in a manner designed for recovery without loss of control or release of radioactivity.
risk	The product of probability and consequence. In this report, the radiological risk of a scenario is the population dose equivalent resulting from that scenario multiplied by the probability that the scenario will actually occur.
risk assessment	A qualitative or quantitative evaluation of the environmental and/or health risk resulting from exposure to a chemical or physical agent; combines exposure assessment results with toxicity assessment results to estimate risk.
roentgen	The special unit of exposure. One roentgen equals 2.58×10^{-4} coulomb per kilogram of air.
Rustler Formation	The evaporite beds, including mudstones, of probable Permian age that immediately overlie the Salado Formation in which the WIPP disposal levels are built.

Salado Formation	The Permian age evaporite formation. A geologic waste repository at the Los Mendanos site would be constructed within this formation.
scenario	A particular chain of hypothetical circumstances that could, in principle, release radioactivity or hazardous chemicals from a repository or during a transportation accident.
shaft	A man-hole; either vertical or steeply inclined, that connects the surface with the underground workings of a mine.
shelf	In the ocean, the zone extending from the line of permanent immersion to the depth where there is a marked or rather steep descent to great depths.
slurry	A suspension of fine particles in a liquid, in which the solid constituents are easily carried along by the liquid.
solubility	The degree to which a compound in its pure state will dissolve; water is the solvent used for determining aqueous solubility of a compound.
sorption	A general term used to encompass the process of adsorption (surface retention of a solid, liquid, or gas by a solid or liquid), absorption (penetration of substances into the bulk of a solid or liquid), and desorption.
source term	The kinds and amounts of radionuclides and/or hazardous chemicals that make up the source of a potential release.
specific activity	Total activity of a given nuclide per gram of a compound, element, or radioactive nuclide.
specific gravity	The ratio of the density of the compound in its pure form to the density of water. Compounds with a specific gravity of less than 1.0 (the specific gravity of pure water) will tend to float on water when they occur as a pure product.
spent fuel	Nuclear reactor fuel that, through nuclear reactions, has been sufficiently depleted of fissile material to require its removal from the reactor.
stratigraphy	The study of rock strata, especially of their distribution, deposition, and age.

Supplement to the Environmental Impact	For purposes of the Waste Isolation Pilot Plant, this SEIS is supplementary information to that provided in the Final Environmental Impact Statement prepared in 1980. This SEIS evaluates the environmental consequences of the proposed action as modified since 1980 in light of new information and assumptions.
sylvite	The mineral, potassium chloride, used as a fertilizer.
syncline	A fold in rocks in which the strata dip inward from both sides toward the axis.
tectonic activity	Movement of the earth's crust such as uplift and subsidence and the associated folding, faulting, and seismicity.
tectonism	The structural behavior of an element of the earth's crust during or between major cycles of sedimentation.
teratogen	An agent causing the formation of a congenital anomaly or monstrosity.
Test Phase	A program proposed by DOE to reduce uncertainties asssociated with factors which may affect repository performance and to demonstrate waste handling operations.
threshold limit values (TLV)	Threshold limit values refer to airborne concentrations of a substance and represent conditions under which it is believed that nearly all workers may be repeatedly exposed day after day without adverse effect. The TLV-TWA is the time-weighted average concentration for a normal 8-hour workday and a 40-hour workweek to which nearly all workers may be repeatedly exposed day after day without adverse effect. The TLV-STEL is the concentration to which orders can be exposed continuously for a short period of time without suffering from irritation, chronic or reversible tissue damage, and narcosis of sufficient degree to increase the likelihood of accidental injury.
transfer cell	An interim area of the waste handling building used to offload TRUPACTS before they are brought into the building and opened.
transmutation	Any process in which a nuclide is transformed into a different nuclide, or more specifically, when transformed into a different element by a nuclear reaction.

transuranic nuclide	A nuclide with an atomic number (number of protons) greater than that of uranium (92). All transuranic nuclides are produced artificially and are radioactive.
transuranic (TRU) waste	TRU waste results primarily from plutonium reprocessing and fabrication as well as research activities at DOE defense installations. It is material contaminated with alpha-emitting radionuclides that are heavier than uranium with half-lives greater than 20 years and in concentrations greater than 100 nanocuries per gram (nCi/g).
TRUPACT	Transuranic Package Transporter.
TRUPACT-II	TRUPACT-II is the package designed to transport contact-handled TRU waste to the WIPP site. It is a cylinder with a flat bottom and a domed top that is transported in the upright position. The major components of the TRUPACT-II are an inner, sealed, stainless steel containment vessel within an outer, sealed, stainless steel containment vessel. Each containment vessel is non-vented and capable of withstanding 50 pounds of pressure per square inch (psi). The inner containment vessel cavity is approximately six feet in diameter and six feet tall, with a capability of transporting fourteen 55-gallon drums, two standard waste boxes, or one box and 7 drums.
unity	One.
upper bounding accident	The worst accident that, by agreement, need be taken into account in devising protective measures.
void volume	The total volume in a matrix not occupied by the matrix material.
TRU waste	See transuranic (TRU) waste.
vapor density	The weight of a given volume of a chemical relative to the weight of the same volume of air. A compound with a vapor density close to that of air will be miscible with air; a compound with a vapor density much less or much greater than air will tend to remain unmixed and stratify in an atmospheric column.
vapor pressure	The pressure exerted by a vapor in equilibrium with a liquid or solid. For example, a liquid with a high vapor pressure is more volatile or more easily passed into the atmosphere by evaporation.

volatile organic compound (VOC)	Any compound containing carbon and hydrogen in combination with any other element which has a vapor pressure of 1.5 pounds per square inch absolute (77.6 mm Hg) or greater under actual storage conditions.
volatilization	To evaporate at normal temperatures and pressures.
vuggy	Rock containing small cavities which may or may not be infilled.
Waste Acceptance Criteria (WAC)	The DOE document describing the criteria by which unclassified transuranic waste will be accepted for emplacement at the WIPP and the basis upon which these criteria were established.
Waste Isolation Pilot Plant (WIPP)	The facility near Carlsbad, New Mexico that has been designated to be an experimental and operational site for evaluating disposal capabilities of bedded salt for defense-generated transuranic waste.
waste form	The condition of the waste. This phrase is used to emphasize the physical and chemical properties of the waste.
waste matrix	The material that surrounds and contains the waste and to some extent protects it from being released into the surrounding rock and groundwater. Only material within the canister (or drum or box) that contains the waste is considered part of the waste matrix.

ABBREVIATIONS AND ACRONYMS

ACGIH	American Conference of Government Industrial Hygienists
AEA	Atomic Energy Act
AEC	U.S. Atomic Energy Commission
AED	aerodynamic-equivalent diameter
AEOC	Alternative Emergency Operations Center
AIC	acceptable daily levels for chronic intake
AIPC	All Indian Pueblo Council
AL	Albuquerque Operations Office of the Department of Energy
ALARA	as low as reasonably achievable
ALI	Annual Limit of Intake
Am	americium
AMAD	activity median aerodynamic diameter
AMSL	above mean sea level
ANL	Argonne National Laboratory
ANS	American Nuclear Society
ANSI	American National Standards Institute
ASWS/C&S	air support weather shield/certification and segregation
atm	atmosphere
ATSDR	Agency for Toxic Substances and Disease Registry
ATSF	Atchison, Topeka and Santa Fe Railroad
B	boron
BDAT	best demonstrated available technology

BDB	beyond design basis
BEIR	Committee on Biological Effects of Ionizing Radiation
BLM	Bureau of Land Management
Br	bromine
BSEP	Brine Sampling and Evaluation Program
Ca	calcium
CAS	Chemical Abstract System
CCA	comprehensive cooperative agreement
CCDF	complementary cumulative distribution function
Ce	cerium
CEDE	committed effective dose equivalent
CEQ	Council on Environmental Quality
Cf-252	californium-252
CFR	Code of Federal Regulations
CH	Contact-handled; refers to TRU waste not requiring shielding or specially designed facilities for handling
Ci	curie
Ci/L	curies per liter
Cl	chlorine
Cm	curium
cm	centimeter
CO	carbon monoxide
CPFs	carcinogenic potency factors
Cs	cesium
CTUIR	Confederated Tribes of the Umatilla Indian Reservation

CVSA	Commercial Vehicle Safety Alliance
CY	calendar year
dB	decibel
DCF	dose conversion factor
DEIS	Draft Environmental Impact Statement
DHLW	Defense High-Level Waste
DOE	U.S. Department of Energy
DOI	U.S. Department of the Interior
DOT	U.S. Department of Transportation
DRZ	disturbed rock zone
DVM	Distributed Velocity Method
DWMP	Defense Waste Management Plan
EDE	effective dose equivalent
EEG	Environmental Evaluation Group
EID	Environmental Improvement Division
EIS	Environmental Impact Statement
EMP	Ecological Monitoring Program
EO	Executive Order
EOC	Emergency Operations Center
EP	extractive procedure
EPA	U.S. Environmental Protection Agency
ER	emergency response
ERDA	U.S. Energy Research and Development Administration
°F	degrees Fahrenheit

FDA	U.S. Food and Drug Administration
Fe	iron
FEIS	Final Environmental Impact Statement
FEMA	Federal Emergency Management Agency
FLPMA	Federal Land Policy and Management Act
FRERP	Federal Radiological Emergency Response Plan
FRMAP	Federal Radiological Monitoring and Assessment Plan
FSAR	Final Safety Analysis Report
ft	foot
ft^2	square foot
ft^3	cubic foot
FY	fiscal year
g	gram
g/ft^3	grams per cubic foot
g/L	grams per liter
gal	gallon
H_2S	hydrogen sulfide
HEPA	high-efficiency particulate air
HI	hazard index
HONG	high organic/newly generated
HMTA	Hazardous Material Transportation Act
HSWA	Hazardous and Solid Waste Amendments
HVAC	heating, ventilation, and air conditioning system
IAEA	International Atomic Energy Agency
IAPI	Office of Intergovernmental Affairs and Public Information

IARC	International Agency for Research on Cancer
ICRP	International Commission on Radiological Protection
ICV	inner containment vessel
IDB	Integrated Data Base
IDLH	immediate danger to life and health
INEL	Idaho National Engineering Laboratory
INF	infrequent
IRIS	Integrated Risk Information System
ISC	Industrial Source Complex (model)
ISCLT	Industrial Source Complex Long Term (model)
ISCST	Industrial Source Complex Short Term (model)
IUPAC	International Union of Pure and Applied Chemistry
JNACC	Joint Nuclear Accident Coordinating Center
K	potassium
kg	kilogram
km	kilometer
L	liter
LANL	Los Alamos National Laboratory
lb	pound
LCF	latent cancer fatality
LEC	lowest effect levels
LET	linear energy transfer
LIM	limiting
LLNL	Lawrence Livermore National Laboratory

LONG	low organic/newly generated
m	meter
m^3	cubic meter
MB	marker bed
MCL	maximum containment or concentration limit
MPa	MegaPascal
MF	moderate frequency
mg	microgram
Mg	magnesium
mg/kg	milligrams per kilogram
mi	mile
mi^2	square mile
mm	millimeter
MOU	Memorandum of Understanding
mph	miles per hour
mrem	millirem; one thousandth of a rem (0.001 rem)
MSHA	Mining Safety and Health Administration or Mine Safety and Health Act
NA	not applicable or not available
Na	sodium
NAS	National Academy of Sciences
NCAI	National Congress of American Indians
nCi/g	nanocuries per gram
NCRP	National Council on Radiation Protection and Measurements
NE	not evaluated

NEFTRAN	network flow and transport code
NEPA	National Environmental Policy Act of 1969
NIOSH	National Institute of Occupational Safety and Health
NMDG&F	New Mexico Department of Game and Fish
NO	nitrogen oxide
NO_2	nitrogen dioxide
NOAEL	no observed adverse effect level
NO_x	nitrogen oxides
Np	neptunium
NRC	U.S. Nuclear Regulatory Commission
NRHP	National Register of Historic Places
NTS	Nevada Test Site
NUPAC	Nuclear Packaging Company
NWPA	Nuclear Waste Policy Act of 1982
NWPAA	Nuclear Waste Policy Act Amendments of 1987
O_3	ozone
OCRWM	Office of Civilian Radioactive Waste Management
OEMP	Operational Environmental Monitoring Program
ONWI	Office of Nuclear Waste Isolation
ORNL	Oak Ridge National Laboratory
OSHA	Occupational Safety and Health Administration or Occupational Safety and Health Act
PAB	performance assessment brine
Pb	lead
PE-Ci	plutonium-equivalent curie

ppm	parts per million
PREPP	Process Experimental Pilot Plant
PSA	Pacific States Alliance
psi	pounds per square inch
psig	pounds per square inch gauge
Pu	plutonium
Pu-238	plutonium-238
Pu-239	plutonium-239
PVC	polyvinyl chloride
QA	Quality Assurance
R	roentgen
R&D	Research and Development
RADTRAN II	A computer model for determining potential radiation doses during transit
RAM	radioactive materials
RAP	Radiological Assistance Program
RAT	Radiological Assistance Team
RBP	radiological baseline program
RCF	Retrievable Containment Facility
RCRA	Resource Conservation and Recovery Act
REAC/TS	Radiation Emergency Assistance Center/Training Site
REPS	Regulatory and Environmental Programs Section, Westinghouse
RFP	Rocky Flats Plant
RH	Remote-handled; refers to TRU waste requiring shielding of waste containers or waste-handling facilities
RHMC	Radioactive and Hazardous Materials Committee

ROD	Record of Decision
Ru	ruthenium
RWCTF	Radioactive Waste Consultation Task Force
RWMC	Radioactive Waste Management Complex
SARP	Safety Analysis Report for Packaging
Sb	antimony
SEIS	Supplemental Environmental Impact Statement
SNL	Sandia National Laboratories
SO_2	sulfur dioxide
SOP	standard operating procedure
SPDV	Site and Preliminary Design Validation
SPHEM	Superfund Public Health Evaluation Manual
SPI	slagging pyrolysis incineration
SPI	slagging pyrolysis incineration
Sr	strontium
SRF	Supercompaction and Repackaging Facility
SRS	Savannah River Site
SS&EP	Safety, Security, and Environmental Protection
SSEB	Southern States Energy Board
STEP	States Training and Educational Program
SWB	standard waste box
SWC	standard waste containers
SWEPP	Stored Waste Examination Pilot Plant
SWIFT II	Sandia Waste Isolation Flow and Transport Code

TCC	TRANSCOM Control Center
TCE	trichloroethylene
TDEM	time domain electromagnetic methods
TDS	total dissolved solids
Th	thorium
TI	Transport Index
TLV	threshold limit value
TMF	TRUPACT Maintenance Facility
TR	Technical Representative (DOE)
TRANSCOM	Transportation Tracking and Communications System
TRU	transuranic
TRUPACT	Transuranic Package Transporter
TRUPACT-II	Type B Shipping Container
TSA	transuranic storage area
TSP	total suspended particles
TWA	time-weighted average
TWI	TRU Waste and Integration
U	uranium
UNAMAP	Users Network for Applied Modeling of Air Pollution
USC	United States Code (of laws)
USFWS	U.S. Fish and Wildlife Service
VOC	volatile organic compound
vol	volume
W	watts
WAC	Waste Acceptance Criteria

WACCC	Waste Acceptance Criteria Certification Committee
WSC	Waste Storage Cell
WEC	Westinghouse Electric Corporation
WERF	Waste Experimental Reduction Facility
WGA	Western Governors' Association
WHB	waste handling building
WIEB	Western Interstate Energy Board
WIIP	WIPP Integrated Institutional Program Plan
WIPP	Waste Isolation Pilot Plant
WSC	Waste Storage Cell
yr	year
μ	micron; unit of length equal to 10^{-6} meters

UNIVERSITY OF CALIFORNIA

LIST OF PREPARERS

Those who prepared this final supplement to the Final Environmental Impact Statement for the Waste Isolation Pilot Plant are identified below.

The overall effort was initially led by W. John Arthur III and subsequently by Daryl Mercer who served as DOE SEIS Project Manager. Assistance was provided to DOE-AL by Advanced Sciences, Inc., and its subcontractors, Roy F. Weston, International Technology, the S. M. Stoller Corporation, and Jacobs Engineering Group. The persons contributing to the SEIS are listed below.

Volume 1		Principals
Section 1	Purpose and Need for Action	D. Lechel, R. Hansen
Section 2	Background: An Overview of WIPP	D. Lechel, R. Hansen, K. Knudtsen, J. McFee, E. Louderbough
Section 3	Description of the Proposed Action and Alternatives	D. Jones, D. Lechel, K. Knudtsen, E. Louderbough
Section 4	Description of the Existing Environment	S. McBee, C. Comstock, D. Diener
Section 5	Environmental Consequences	S. McBee, C. Comstock, K. Knudtsen, M. Merritt, D. Diener, S. Beranich, W. McMullen, S. Everette, S. Eagan, S. Kline, L. Adcock, C. Fredrickson, R. Murphy
Section 6	Mitigation Measures	S. McBee, C. Comstock, J. McFee, W. McMullen
Section 7	Unavoidable Adverse Impacts	C. Kennedy, R. Van Vleet
Section 8	Short-Term Uses and Long-Term Productivity	C. Kennedy, R. Van Vleet
Section 9	Irreversible and Irretrievable Commitments of Resources	C. Kennedy, D. Diener
Section 10	Environmental Regulatory, Institutional, and Oversight Requirements	R. Hansen, D. Lechel

Volume 2 (Appendices)		Principals
Appendix A	Waste Isolation Pilot Plant Waste Acceptance Criteria	S. McBee
Appendix B	Waste Characteristics	S. McBee, W. McMullen, R. Murphy
Appendix C	Transportation Emergency Planning	S. Kouba
Appendix D	Transportation and Transportation-Related Risk Assessment	W. McMullen, S. Eagan, S. Everette, S. Kline, S. Beranich
Appendix E	Hydraulic and Geotechnical Measurements at the WIPP Horizon	C. Comstock, C. Wood, S. McBee
Appendix F	Radiological Release and Dose Modeling for Permanent Disposal Operations	C. Fredrickson
Appendix G	Toxicity Profiles, Risk Assessment Methodology, and Models for Chemical Hazards	K. Knudtsen, M. Flowers, G. Lage
Appendix H	Public Information and Intergovernmental Affairs	A. Marshall, T. Loughead
Appendix I	Methods and Data Used in Long-Term Consequence Analyses	M. Merritt, K. Knudtsen
Appendix J	Bibliography	Not Published in Final
Appendix K	DOE Reading Rooms and Public Libraries	T. Loughead
Appendix L	Containers and Casks for Shipping TRU Waste	J. Cruse
Appendix M	Summary of the Management Plan for the Trucking Contractor	S. Beranich

Appendix N	Re-evaluation of Radiation Risks from WIPP Operations	B. Kelly
Appendix O	Test Plan Summary	R. McKinney
Appendix P	TRU Waste Retrieval, Handling, and Processing	J. Cruse, W. McMullen, K. Knudtsen

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Brief biographic summaries for the preparers are provided below.

Larry Adcock, Economist, U.S. Department of Energy

B.A. Economics, University of New Mexico, 1968
M.A. Economics, University of New Mexico, 1972
Ph.D. Economics and Urban/Regional Planning, University of New Mexico, 1983

Dr. Adcock is a Regional Economist with 20 years' experience in regional economic impact analyses and regional econometric model building. His experience includes economic impact analyses for more than a dozen projects. Dr. Adcock provided the socioeconomic component analysis for the WIPP FEIS of 1980. He has directed a university business and economic research agency and served as Cabinet Secretary for Economic Development and Tourism for the State of New Mexico.

Sandra J. Beranich, Staff Scientist, Roy F. Weston, Inc.

B.A. Geology, Southern Illinois University, 1968
M.A. Geography, University of Oregon, 1973

Ms. Beranich has 13 years of experience in environmental document preparation and multidisciplinary studies for evaluation of proposed Federal and private actions on public land, in determining the adequacy of Federal agency and environmental documents, and in coordinating and interfacing Federal land-use planning documents with NEPA requirements. She has coordinated and prepared environmental assessments, developed monitoring and surveillance plans for remedial actions, and coordinated alternate site selection teams for disposal sites.

Charles R. Comstock, R.G. C.E.G., Project Manager, Hydrogeologist, Roy F. Weston, Inc.

B.S. Geology, San Jose State University, 1967
Graduate Studies in Geology, San Jose University, 1972 - 1974
Registered Geologist, State of California
Certified Engineering Geologist, State of California

Mr. Comstock has 14 years of experience in hydrology and engineering geology, primarily related to aquifer contamination assessments, nuclear waste repository siting,

nuclear power plant siting and licensing, and groundwater resource investigations. He participated in prominent nuclear waste programs, including the Basalt Waste Isolation Project, the National Waste Terminal Storage Program, and the Uranium Mill Tailings Remedial Action Project.

Jody D. Cruse, Private Consultant

B.S. Materials Science and Engineering, Washington State University, 1986
M.S. Materials Science and Engineering, Washington State University, 1988

Ms. Cruse has had experience in cask licensing, corrosion analysis, and TRU waste characterization, contributing to several DOE documents. She assisted in obtaining NRC certification for TRUPACT II.

Richard A. Diener, Wildlife Biologist, Advance Sciences, Inc.

B.S. Zoology, University of Illinois, 1952
M.S. Zoology, University of Arkansas, 1956
Ph.D. Zoology, University of Oklahoma, 1965

Dr. Diener is a biologist with more than 30 years of experience in developing and conducting research in various biological disciplines. These include herpetology, estuarine fishery biology and hydrology, crustacean physiology, and the evaluations of impacts from water-resource development projects on various fishery and wildlife habitat types. He has prepared or participated in a large number of environmental assessments and environmental impact statements.

Steven L. Eagan, Transportation Engineer, S. M. Stoller Corporation

B.S. Civil Engineering, University of New Mexico, 1974
M.S. Civil Engineering, Massachusetts Institute of Technology, 1977
M.A. Public Administration, University of New Mexico, 1984

Mr. Eagan has over 15 years of experience in the field of transportation systems. He has provided technical assistance on transportation-related issues in nuclear waste management and conducted transportation risk assessment for proposed TRU waste shipments.

Steven E. Everette, Senior Technical Staff, S. M. Stoller Corporation

B.S. Biology and Chemistry, Western Oregon State College, 1968

Mr. Everette has 17 years' experience in transuranic and low-level waste management. He contributed to the WIPP EIS and conducted technology projects for DOE transuranic and low-level waste retrieval, transportation, and confinement. Mr. Everette was a member of the WIPP Waste Acceptance Criteria Committee.

Mary H. Flowers, Environmental Toxicologist, Advanced Sciences, Inc.

B.S. Zoology, Ohio State University, 1978
M.S. Environmental Toxicology, University of Arizona, 1981

Ms. Flowers is an Environmental Toxicologist with 7 years of experience in hazardous-material assessments and waste management. She has prepared environmental assessments and remedial investigation plans. She has prepared public health impact analyses and site characterization for hazardous and mixed-waste sites.

Craig L. Fredrickson, Principal, Benchmark Environmental Corporation

B.S. Nuclear Engineering, Pennsylvania State University, 1973

Mr. Fredrickson has more than 16 years of diversified experience within the nuclear industry with an emphasis on nuclear safety and radioactive mixed waste management. He has conducted various radiological, environmental, and risk analyses and has contributed to the development of nuclear facility safety standards and criteria. He has also participated in over 30 safety analysis reports as well as NEPA compliance documentation for the WIPP, weapons assembly facilities, thorium handling facilities, and decontamination and decommissioning projects.

Roger P. Hansen, Senior Staff Consultant/Project Manager, IT Corporation

B.S. Journalism, University of Illinois, 1951
J.D. University of North Carolina, 1962

Mr. Hansen has a multidisciplinary background in environmental law, land use and environmental planning, and communications. He has prepared complex permitting documents for major hazardous-waste management facilities. He also conducted and prepared environment assessments and impact statements on nuclear waste repositories. He organized and supervised comprehensive environmental assessments for major mining, energy, and recreation developments, developed methodologies for evaluating and ranking alternative industrial sites according to a set of criteria, and prepared documentation in support of expert testimony in judicial and administrative proceedings. He has served for 6 years as an Adjunct Professor of Environmental Law at the University of Denver College of Law and the Colorado School of Mines.

Dale C. Jones, Principal Project Leader, Roy F. Weston, Inc.

B.S. Mining Engineering, University of Arizona, 1970

Mr. Jones has over 12 years of experience in the preparation of environmental assessments and impact statements. He has prepared and managed the preparation of such documents for uranium mining and reclamation projects with the U.S. Department of the Interior and for the U.S. Department of Energy's Uranium Mill Tailings Remedial Action (UMTRA) Project.

Brian A. Kelly, Senior Health Physicist, IT Corporation

B.S. Physics, University of Notre Dame, 1972
M.S. Environmental Engineering, Rensselaer Polytechnic Institute, 1974
M.B.A. Business Administration, Vanderbilt University, 1987

Mr. Kelly is a health physicist who has experience in the areas of environmental monitoring, applied health physics, ALARA evaluations, radiation protection procedures, and criticality safety. He has prepared radiation and cancer risk assessments, developed and conducted training courses in Basic Radiation Protection, and participated in oversight teams to assess health physics and waste management policies at Oak Ridge and Sandia National Laboratories.

Colburn E. Kennedy, Senior Health and Safety Specialist, Advanced Sciences, Inc.

B.S. Occupational Safety and Health, Central Washington University, 1980

Mr. Kennedy is a diversified health and safety specialist with over 9 years' experience in engineering and human-relations aspects of safety and health. He has expertise in evaluating the safety aspects of engineering designs and providing safety management oversight.

Stephen C. Kline, Technical Staff, S. M. Stoller Corporation

B.S. Mechanical Engineering, Loyola University, 1970
M.S. Engineering, University of California at Los Angeles, 1974

Mr. Kline is a registered professional with 16 years of experience in radioactive-waste management and nuclear power generation. His areas of expertise include the development and implementation of long-range plans for waste management, disposal, and transportation operations and risk management for radioactive-waste transportation.

Karen Knudtsen, Project Scientist, IT Corporation

B.S. Soil Science, Ohio State University, 1977
M.S. Soil Chemistry, University of Florida, 1983

Ms. Knudtsen is a soil/environmental chemist with 10 years' experience in solid- and hazardous-waste management and environmental assessment. Her experience includes the evaluation of hazardous and radioactive mixed-waste characteristics and mechanisms of contaminant transport in the environment, the preparation of regulatory summaries, the development of technical positions regarding RCRA and CERCLA regulatory compliance and permitting assistance for hazardous-waste facilities.

Gary L. Lage, Project Director/Toxicologist, Roy F. Weston, Inc.

B.S. Pharmacology, Drake University, 1963
M.S. Pharmacology, Drake University, 1965
Ph.D. Pharmacology, University of Iowa, 1987

Dr. Lage has over 20 years' experience in all phases of toxicology and associated assessment of chemical risk. He was heavily involved in the academic development of toxicology as a scientific discipline through academic appointments at the University of Kansas and the University of Wisconsin. He served as Project Director/Senior Scientist for several major Health Risk Assessment programs for hazardous waste remedial action programs and for proposed hazardous waste incinerators. In addition, Dr. Lage has 20 years' experience in toxicological research aimed at identifying the role of altered chemical disposition in relation to the ultimate toxic effect. This mechanistic research approach has been funded by several Federal agencies and national foundations.

David J. Lechel, Project Director, Roy F. Weston, Inc.

B.S. Fisheries Biology, Michigan State, 1972
M.S. Fisheries Biology, Michigan State, 1974

Mr. Lechel has over 15 years of experience in project management of multidisciplinary environmental studies, regulatory analyses, and environmental site monitoring. He has been responsible for the design, conduct, management and report preparation for extensive environmental assessments of radioactive and mixed-waste disposal sites, hazardous/toxic waste sites, proposed coal mines, power plants, and waste water treatment facilities.

Ellen T. Louderbough, Environmental Scientist/Ecologist, IT Corporation

B.S. Nursing, Skidmore College, 1968
M.S. Biology, University of New Mexico, 1976
Ph.D. Biology, University of New Mexico, 1983

Dr. Louderbough is an ecologist and an environmental scientist specializing in the regulatory issues of waste management and environmental assessment. Her field experience as an ecologist includes directing quarterly soil surveys to assess the extent of salt deposition at the WIPP site and surveying shale-derived soils to study the process of vegetation-soil interactions. She has comprehensive knowledge of RCRA regulations and the NEPA documentation process relative to issues dealing with hazardous and mixed waste.

Tracy Loughead, Public Information Specialist, Jacobs Engineering Group, Inc.

B.A. Psychology, Bucknell University, 1979

Ms. Loughead has extensive experience writing and coordinating press releases; writing, coordinating, and disseminating public information documents; and coordinating public meetings and hearings. She has also managed public information mail list databases.

Ann Marshall, Manager of Community Relations, Advanced Sciences, Inc.

B.A. English, University of Colorado, 1964
M.P.S. Communications Arts, Cornell University, 1976

Ms. Marshall has 20 years of public involvement experience. She has worked on a variety of hazardous-waste management projects which were part of programs including Superfund, Resource Conservation, and Recovery Act (RCRA), Chemical Emergency Preparedness, and Department of Energy Installation Restoration Program.

Shara Mount McBee, Geotechnical Engineer

B.S. Geology, Southmost Missouri State University, 1976
B.S. Geological Engineering, University of Missouri-Rolla, 1978
M.S. Geological Engineering, University of Missouri-Rolla, 1982

Ms. McBee is an environmental and geotechnical engineer with 10 years of experience in program management, environmental engineering, and geotechnical engineering. She has managed and participated in Remedial Investigations and Feasibility Studies for more than 30 hazardous waste sites. She has prepared Environmental Assessments and RCRA Part B applications.

John N. McFee, Senior Project Engineer, IT Corporation

B.S. Chemical Engineering, Clarkson College of Technology, 1961
Nuclear Power Engineering School, 1974
Idaho National Engineering Laboratory

Mr. McFee is a chemical engineer with 22 years of experience in chemical synthesis, energy recovery, and waste management process design and development. Recent projects concerned incineration of hazardous and radioactive wastes.

Roy F. McKinney, Project Manager, IT Corporation

B.S. Geological Engineering, New Mexico State University, 1973
M.S. Geological Engineering, University of Nevada-Reno, 1976

Mr. McKinney has over 12 years of professional experience, including technical and managerial responsibilities, in performing geologic and geotechnical investigations for both surface and subsurface facilities. Specific technical expertise covers geologic and

geotechnical issues related to siting and developing a nuclear waste repository for DOE and evaluation of site conditions for a variety of facilities and structures, including nuclear power plants, uranium mill tailing dam sites, and large commercial and residential developments. He is also familiar with the RCRA permitting process

William H. McMullen, Manager, S. M. Stoller Corporation

B.S. Engineering Mechanics, U.S. Air Force Academy, 1972
M.S. Metallurgy, Columbia University, 1973
M.A. Business Management, NM Highlands University, 1977

Mr. McMullen has over 15 years of experience in government research and development projects, transuranic waste management, high-level waste management, facility planning, NEPA compliance and construction, and project management. Mr. McMullen has been responsible for developing NEPA strategy and compliance options for buried TRU waste, preparing long-range waste management master plans, and developing options for optimizing costs and schedules of program elements to achieve permanent disposal of contact-handled, remote-handled, special case and buried TRU contaminated wastes. He has also been responsible for assessing specific and cumulative risks of transporting TRU wastes from generating and storage sites, and coordinating the efforts of TRU-waste generating sites to implement technology for waste volume reduction.

Melvin L. Merritt, Principal Scientist, Advanced Sciences, Inc.

B.S. Physics, California Institute of Technology, 1943
Ph.D. Physics, California Institute of Technology, 1950

Dr. Merritt has 38 years of experience in nuclear weapons effects, weapons test safety, and environmental impact assessment. Dr. Merritt has prepared four EAs and EISs involved with operating a national laboratory identifying sites for conducting nuclear tests, WIPP, and uranium mill tailings remediation. He was a member of an NAS subcommittee on fallout and has co-edited and authored numerous technical and scientific articles.

Robert O. Murphy, Principal Scientist, Roy F. Weston, Inc.

B.S. Industrial Management, Georgia Institute of Technology, 1975
M.S. Applied Nuclear Science, Georgia Institute of Technology, 1978
Ph.D. Nuclear Engineering, Georgia Institute of Technology, 1986

Dr. Murphy has 9 years of experience in the radiation protection field. He has specialized in operational health physics, radiation measurements, and radiological risk assessments. He has been involved in the preparation of EAs for the Uranium Mill Tailings Remedial Action Program and various RI/FSs.

Rick J. Van Vleet, Nuclear Engineer, Advanced Sciences, Inc.

B.S. Nuclear Engineering, Kansas State University, 1981
Ph.D. Engineering, Kansas State University, 1985

Dr. Van Vleet is an engineer with 4 years' experience in radionuclide transport in saturated media, computer-code verification and benchmarking, model validation, and the preparation of safety analysis reports.

Craig J. Wood, P.G., Project Geologist, Roy F. Weston, Inc.

B.S. Geology, Eastern New Mexico University, 1982
Professional Geology Registration State of Florida

Mr. Wood has 7 years of experience as a geologist and a hydrogeologist in the design, implementation, and evaluation of programs to evaluate soils, groundwater, and hydrogeologic and hydrodynamic conditions as they apply to hazardous waste management. He has coordinated all aspects of technical projects and supervised project definition, data collection and evaluation, and final report writing.

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